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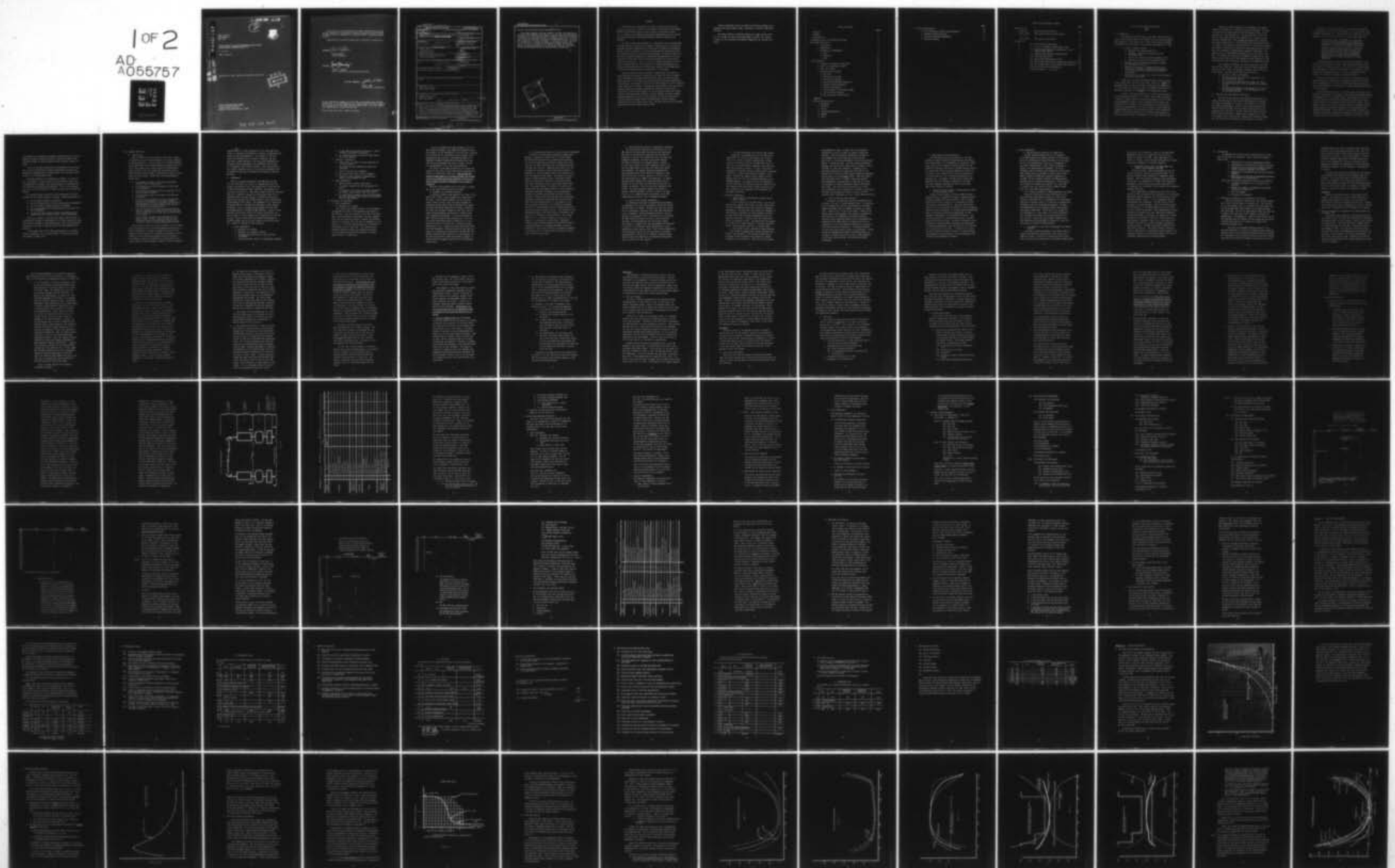

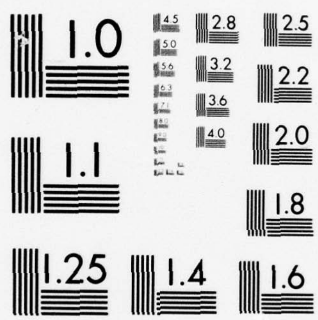

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RADC-TR-78-121
Phase Report
May 1978

TEPER TECHNICAL EVALUATION PROGRAM EVALUATION AND RESTRUCTURING; RESEARCH REPORT 2-77

R. L. Feik

SUNY at Buffalo

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ROME AIR DEVELOPMENT CENTER
Air Force Systems Command
Griffiss Air Force Base, New York 13441

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The original goals of the TEP were lofty and benefits were intended for every facet of the DCS from day-to-day O&M through system characterization and engineering. There are those who question how well the TEP has met these goals. This research report examines this issue and quantizes the cost benefits by tabulating the TEP numerous outputs and by estimating the cost of contracts that would have been required to produce the equivalent output products. The conclusion is that the TEP has contributed dramatically to

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the DCS, but may have been biased toward O&M activities.

This report examines the present status of the TEP, and discusses the constraints and impediments that raise the cost and limit the effectiveness and productivity. The study investigates possible future program courses, to accommodate the enumerated hindrances, to sharpen the goals of a future TEP, and to reduce the cost while increasing the demonstrable outputs. A future TEP configuration is defined, including: a re-oriented and more definitive set of objectives, a reformulated approach and analysis concept, and a specific set of output products to be derived to support the DCA Quality Assurance program as described in the DCA Circular 310-70-57, and also to provide the DCA Engineering system characterization and data base.

PREFACE

This effort was conducted by R.L. Feik in association with State University of New York under the sponsorship of the Rome Air Development Center Post-Doctoral Program for the Defence Communication Agency. Mr. R.I. Hughes of the Defense Communication Engineering Center, DCA was task project engineer and provided overall technical direction and guidance.

The RADC Post-Doctoral Program is a cooperative venture between RADC and some sixty-five universities eligible to participate in the program. Syracuse University (Department of Electrical and Computer Engineering), Purdue University (School of Electrical Engineering), Georgia Institute of Technology (School of Electrical Engineering), and State University of New York at Buffalo (Department of Electrical Engineering) act as prime contractor schools with other schools participating via sub-contracts with the prime schools. The U.S. Air Force Academy (Department of Electrical Engineering), Air Force Institute of Technology (Department of Electrical Engineering), and the Naval Post Graduate School (Department of Electrical Engineering) also participate in the program.

The Post-Doctoral Program provides an opportunity for faculty at participating universities to spend up to one year full time on exploratory development and problem-solving efforts with the post-doctorals splitting their time between the customer location and their educational institutions. The program is totally customer-funded with current projects being undertaken for Rome Air Development Center (RADC), Space and Missile Systems Organization (SAMSO), Aeronautical Systems Division (ASD), Electronic Systems Division (ESD), Air Force Avionics Laboratory (AFAL), Foreign Technology Division (FTD), Air Force Weapons Laboratory (AFWL), Armament Development and Test Center (ADTC), Air Force Communications Service (AFCS), Aerospace Defense Command (ADC), HQ USAF, Defense Communications Agency (DCA), Navy, Army, Aerospace Medical Division (AMD), And Federal Aviation Administration (FAA).

Further information about the RADC Post-Doctoral Program can be obtained from Jacob Scherer, RADC, telephone AV 587-2543, COMM (315) 330-2543.

The author wishes to thank Mr. Hughes, Mr. Bugg, and Mr. Dunn, all of the DCEC for their continuing support, and Mr. R.H. Levine, of DCEC, for his direction and helpful suggestions all through this effort.

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The Technical Evaluation Program

(TEP)

I. Introduction

The original published goals of the TEP, then called Technical Visits Program (TVP), were divided into four mutually supporting objectives. The following is a direct quote from the original presentation on Scope Creek - the Air Force implementation of TEP.

A. Acquire, Compile, Analyze
    1. Equipment and system design data
    2. Equipment, subsystem and system measured performance data
    3. Circuit and network measured performance data
    4. Maintenance, operational and logistic data

B. Develop, Apply and Enforce operational, logistic, and maintenance standards

C. Develop and Implement recommendations for cost effective, time-phased, upgrade and modernization of the plant to insure satisfaction of customer requirements

D. Provide DCA data required for system characterization and system engineering.

These were, and still are laudable goals, nearly as good as new, since they have been little used. There are a myriad of problems facing the DCA as the DCS is modernized and upgraded as it is converted to a hybrid and then to a digital structure and as the DCS is converged to the WWMCCS all encompassing concept.

Clearly, the TEP has been able to contribute materially to the maintenance and operation of the DCS. Also, TEP has spawned a number of highly productive continuing programs such as the PMP (Link Assessment Program). Past successes alone, however, are insufficient to justify the continued support of the TEP by DCA, although the O&M Commands will still continue to derive large dividends indefinitely, if they analyze and act on the information derived. The basic question, then, is what, if anything, must be done to the TEP to make it responsive to the future needs of DCA.

Before this basic question can be addressed, the present concept and relevance of the TEP must first be examined. The original title of the program Technical Visits Program (TVP), was in a general way quite descriptive. The TVP team was to visit each pair of sites comprising the end terminals of a link and to make technical observations. This program was dramatically different from previous DCA efforts. The TVP program was very sophisticated in concept. The technical observations were to be made in accordance with highly structured test procedures using premium quality equipment, and conducted by engineers and competent technicians. The program was to be sequentially applied to all of the links in the DCS. The program was originally envisaged for repetition on every DCS link every three years. The program has been modified in some technical ways, but the original goals have not changed materially.

For a number of reasons, the lofty objectives of the TEP have not been fully met. There have been many highly productive outputs, and the longer the program is studied, the more the benefits emerge. However, several facts remain obvious.

A. The cost of TEP is significant.

B. The effectiveness has never been documented to the higher management levels.

C. The cubage of the TEP reports is large, yet there is little demonstrable output available for engineering use.

D. The TEP program appears to many people to be most, if not entirely applicable to the O&M Commands, with little payoff for DCA.

II. Realistic and Cost Effective TEP Goals

Even though many people have expressed reservations concerning the TEP program, most DCA and O&M personnel are aware of the general improvement in the day to day operation of the DCS, since TEP was implemented. Further, most people recognize the indirect benefits of TEP, such as excellent training for young engineers and technicians. However, there has never been an in-depth analysis conducted to portray what outputs are, or could be available, and to examine what changes could be made to reduce the cost and increase usefulness of the products of the TEP.

Although, the original objectives of the TEP were presented in late 1967, as stated in the introduction of this document, this statement is perhaps not a totally clear goal toward which all DCS personnel can aim 'at this juncture.' A better goal might be:

> The sole prime goal of the TEP is a proper characterization of the performance of a communications link, with all elements operating at design standards, to validate the link/path engineering.
>
> There are numerous subordinated goals associated with this prime objective such as to provide a systems engineering data base, to identify poor hardware, etc., but these are also dependent upon achieving the prime goal and meeting the premise "with all elements operating at design standards."

The TEP procedures outline the theoretical approach to calculate the performance of a link. This theoretical method is the one used both by DCA engineers to plan the DCS, and also by industrial designers to implement these plans. The approach is to calculate the performance of three of the major elements shown in Figure 1-1, based upon generally accepted techniques.

As will be covered later, the interface connections and the jack field channel ends are not included since they should introduce no degradation. The link calculated performance is then the sum of the performance calculations of the RF, transmitter/receiver, and mux elements.

The TEP generic approach is to measure each link element, and document the results in the report. Each measured performance should be compared with the calculated value. There should be little deviation between the theoretical and measured values of the electronic devices if the operation and maintenance is proper. There should be only a very minor variation between the measured and calculated antenna and waveguide elements, if the installation and alignment are proper. There should be only a small variation between the theoretical and measured propagation value if the siting and path profile are reasonable. Not shown on the Figure 1-1, is

the possibility of external non-design interactions such as interference from other radiating emitters, cross-talk between interconnecting cables or other situations where unplanned signals intrude.

If all of the above theoretical and measurement results agree, then the end-to-end (audio-to-audio) measurements should be the appropriate integrated sum of these values, and also should agree closely with the calculated value.

The broad question to be answered by the TEP - in so far as DCA is concerned - is quite easy to state; 'Does the actual link as implemented, installed, and operated perform in accordance with the theoretical and design calculations?' If not, the corollary issue is; 'how much deviation is there and where does the disparity exist?'

This broad question concerning link performance can be subdivided into five rather specific problems. Referencing Figure 2-1:

A. Is the signal strength as expected?

B. Are the transmitter and receiver performing as engineered?

C. Is the multiplex hardware working as designed?

D. Are the interfaces and interconnections truly noise free and transparent?

E. Is the end-to-end (audio-to-audio) performance the integrated sum of A through D above - and as engineered?

There are a number of inter-related issues, that are also of interest, such as, does the performance of the links change with time, with class of equipment, with manufacturer, or any other systematic feature that can ease or adversely effect the DCA engineering of the DCS.

A concomitant goal for the TEP, particularly in the present fiscal environment, is to provide answers to these key questions and issues, at least cost.

III. Present TEP Status

A. Stipulations

When the TEP was first formulated, there were a number of stipulations made, although perhaps not clearly expressed in policy documents. It was obvious, to the original framers of the TEP effort, that certain mandatory conditions must be met if the program was to produce valid and operationally useful results. When the program was initiated in April, 1968, all TEP team participants understood and strove to meet these critical demands. These basic success prerequisite factors were:

1. All equipment brought to Tech Order performance criteria prior to measurement.
2. All equipment and circuits operated to Tech Order or DCS standards.
3. All waveguide components correctly installed and the antenna properly aligned.
4. All measurements made in accordance with TEP test procedures.
5. All test results analyzed on site as the TEP characterization progressed to the degree needed to assure that all data was consistent, and that equipment degradation or other adverse action had not invalidated any documented result.
6. The full analysis of the TEP data performed by the team who conducted the evaluation and the analytical results summarized by the team chief in written form in the report.
7. That a further analysis of the TEP report be conducted by DCA, to form a real life DCS link and transmission structure performance status and history and to create a systems engineering data base.

Unfortunately, there is no clear statement of all of these obvious prerequisites in the TEP implementing documentation. There is presently no general recognition even of the necessity for these rules, and the program has assumed, at best, largely a routine compliance approach with few controls. In a number of cases, the application of these rules is actively opposed by some personnel, because of lack of technical

and
competency/void in their perspective of the real TEP objectives, or isolated concentration on clerical or administrative details of TEP implementation. For example, if the most basic and necessary tenet (1 above) is applied, the team may have to spend additional time fixing and realigning the equipment before measurement, thus scheduling of the team to a subsequent link could be delayed. Thus, administrative and clerical pressure mounts to do whatever measurement work is possible based upon the schedule even though the results are poor.

B. Impediments

There is a general recognition that TEP does not meet all its lofty goals, and there is a nagging doubt that the outputs are worth the cost. Few people have a broad and also in depth understanding of TEP, therefore, these people can only worry and question. They cannot resolve their own concerns. There are a number of reasons for this malaise that will be discussed below, because clearly no corrective actions nor redirection decisions can be made without a full and practical understanding of the issues. The impediments to a technically satisfying TEP are tabulated and discussed in three general groupings. Group 1 includes those problems that are basic and prerequisites to acceptable TEP operation. Group 2 covers important matters that affect the quality of the data, but are not basic to the successful use or application of the TEP outputs. Group 3 lists items that impede the progress of the TEP program, but are not key issues, and for which there are a number of straight forward solutions.

1. Basic Impediments
    a. Equipment not aligned
    b. Equipment not operated correctly
    c. Interconnecting cabling not noise free and transparent
    d. Teams technically unable to repair/align equipment

e. On-site TEP data analysis inadequate to assure internally consistent information.

f. No established goals for specific TEP analysis and output products

2. Important Impediments

a. Teams unable to repair or align equipment due to lack of parts.

b. Tech Orders contain substantive errors and omissions.

c. Lack of some key test equipment.

d. O&M Command TEP report review inadequate

e. Presence of basic design or implementation errors in the hardware or link.

3. Other Impediments

a. TEP measurement schedule impractical

b. No minimum standards for TEP measurement and report

c. No feedback to the field on the TEP measurement and report output products and their utility

d. The usefulness is suspect since the O&M Commands and DCA acknowledge little productive management help from TEP outputs.

C. Discussion of Impediments

1. Basic Impediments

a. Equipment not aligned.

The single most disruptive factor is the pervasive substandard condition of the hardware upon arrival of the TEP team. The basic mission of the team is measurement. When problems are discovered, the team requests that the site personnel repair or realign any degraded devices, and failing this, the team is supposed to do so. Clearly, no 'like new' characterization is possible if the hardware is not 'like new'. The teams and site personnel generally improve the operating condition of the equipment during the TEP process, but rarely achieve full T.O. compliance.

It is not necessary that <u>all</u> equipment be in full and complete alignment, when duplicate equipment exists. For example, if one transmitter at one site and a receiver at the other end of a microwave link are linear, valid measurements are possible. Measurements made on the degraded alternate transmitter and receiver over this link may be interesting, may even be useful, but are not representative of the true link capability.

The result of most TEP evaluations, is a characterization of the link in better than normal operating condition, but worse than 'like new.' <u>Thus the TEP data cannot be used either as an honest portrayal of the DCS as it is in normal day-to-day operation, nor can it be used to depict the DCS as designed or as it could or should be</u>.

This most basic problem lies at the heart of nearly all of the other difficulties with the TEP.

b. Equipment not operated correctly.

A problem, slightly less important now, than in the early days of TEP, is the maloperation of portions of the link. This includes operation of the link with signal levels too high, with the levels through the multiplex varying widely from the standard even though the input and output levels may be correct, operating the link with multiplex ringers on full time, over or under driving hardware, and failure to observe other T.O. operational procedures. In the early phases of TEP, levels and drives were routinely off 5 to 10 db. The latest observations seem to indicate a 4 to 6 db maximum variation for most sites. Certainly a great improvement, but in critical circuitry still more deviation than desirable. Only the in-station and link problems can be absolutely controlled by the TEP team, the signals transiting the station may be correctable, but the same factors that foster the problem, conspire to resist rapid and complete correction for the TEP characterization.

c. Interconnecting cabling not noise free and transparent.

Theoretical calculations, engineering design mathematics, installation checkout and to a large degree the TEP procedures ignore the interconnecting devices. The noise, distortions, and spurious signals that enter the link via these interfaces are not measured directly - although they could be. Experience has shown that this oversight on occasions, ignores some major sources of degradation. Cables, bridges, pads, and amplifiers all have two general trouble modes. One manner is noise or spurious signal generation due to non-linear effects such as, corrosion in connectors or dissimilar metal junctions, cold solder joints, and frayed shield braiding. The second source of trouble is the pick-up of signals from the environment because of cable imbalance, inadequate shielding, inadequate or poor grounding, circulating currents or unplanned high level signal exposure. These interface introduced noise or spurious signals may sometimes be detected directly during the end-to-end link measurements. In the balance of the cases, indirect detection of the problem is possible, but only if the measurement data is carefully collected and is thoroughly analyzed on site. The isolation of the detected problem to the entry device or mechanism, then must be accomplished by special testing. The present TEP team normally fails to surface the problem. The report data submitted is inconsistent. Subsequent analysis cannot resolve whether an undetected problem is a poor measurement, or degraded equipment caused the disparity. Thus, fault isolation is normally impossible at a later date at the HQ location when closer examination of the data may occur.

d. Teams technically unable to repair/align equipment.

The hand-selected engineers and technicians for the TEP teams in the early years were mature and experienced and had both the scientific education and the practical capability to detect the problem and to do the repair and alignment personally, and thus could either "manage" the team or instruct on the repair phases. Further, in the first 6 months the author examined the data from the four teams daily to be sure that errors were caught and corrected. The present teams have predominantly young engineers with little practical experience, thus, they are not able to detect errors, or to aid or show the technicians how to repair the difficulty. On system problems where standard tech order procedures are not adequate or do not apply, the technicians often fail to correct the problem - just as the on-site personnel also failed. The young engineers normally are unable to devise a suitable approach, either to correct the defective T.O. or to measure around the problem, so the TEP measurements are made by rote on degraded equipment.

e. On-site data analysis inadequate.

The TEP teams often make the prescribed measurements in accordance with the test procedures, record the results, and bind them in a bundle. The fact that the test results are not technically consistent with other TEP measurements is not recognized. During subsequent analysis, the disparity, if discovered at all, is unlikely to be unravelled. The TEP reports attribute the error to instrumentation problems, and recomendations that site people pursue the problem, or suggest that more measurements are required. A favorite is to attribute these imponderables to poor grounding or other elusive cause. Only if these disparities are discovered on-site, can the true cause be attacked. Instrumentation errors can be corrected, equipment degradations fixed, and additional non-specified measurements made to clarify the real culprit.

f. No established goals for specific TEP outputs.

Presently, the apparent goal for the TEP is the measurement of a link and the issuance of a report. There is no stated or implied operationally related objective that will suffer if the TEP effort is poor. There is no characterization standard, below which the TEP fails and must be redone. In fact, the passive acceptance of marginal and poor reports remove a powerful incentive to conduct the evaluation properly, and in depth. Perhaps the largest vacuum, however, is the general lack of use of the voluminous TEP data by the DCA/O&M Commands. No program can ever be maintained at peak efficiency and precision when the results of all the extensive work have little visible use and are not well regarded or not regarded at all throughout the management structure.

2. Important Impediments

a. Teams unable to repair/align equipment due to lack of parts.

It is not unusual for the TEP teams to use all the spare tubes, special stock items, or other repair parts on-site in attempting to achieve 'like new' equipment performance. The team then must measure the hardware in this partially repaired, but still degraded condition, or must defer those affected measurements until more parts are available - normally after the alloted evaluation test period is over. The administrative pressure is to just do the 'best possible.' The data collected then is 'best possible,' and that is normally poor.

b. Tech Orders contain substantive error/omissions.

Tech Orders are <u>never</u> fully checked during acceptance of the documents. The logistic review that is attempted covers adjustment and alignment as viewed necessary by the contractor. There is no total system

wide perspective taken to assure that the designated adjustments on each box result in premium 'system' performance. There are normally adjustments available in the equipment for which there are no instructions. Only once, to the authors knowledge, has a major electronic entity - a microwave radio - had all movable adjustments changed, and then the tech order used to attempt to return the radio to 'like new' condition. Needless to say, many basic additions and corrections were made to the document and at least one radio design change was required, and this was one of the better radios. Most Tech Orders have sufficient error or voids so that after several years degradation, no maintainer or TEP team can return the equipment to proper performance based on Tech Order data alone. The only way full recovery of the 'like new' performance can be achieved is to resort to experience, training, and knowledge available to only a few team chiefs and key technicians, or by a Central Region Activity.

c. Lack of some key test equipment.

In general, the TEP teams are well instrumented and are able to do most of their assigned tasks. On occasions, a key instrument may fail and the pressure of the administrative schedule will not permit collection of certain data - there is just a void in the report. There is one general major test equipment void, however, required for the testing of the waveguide and antenna structure. There are often unresolved signal loss or intermodulation problems and the TEP reports are replete with such observations as "the site should investigate this problem." "The site survey was inaccurate." "The maps used were of such scale that accuracy could not be achieved." These blithe and meaningless statements from TEP reports are attempts to explain away 10 db or more of RSL disparity. In one case, since resolved, the antenna was simply malaligned.

d. O&M Command Review Inadequate.

The O&M agencies review and analysis of the TEP reports is highly variable and depends upon the desires and mission grasp of the commander, the technical competence level of the command scientific staff, and the technical competence and drive of the TEP analysis office. Any constructive uses the agency makes of the report is, of course, both a reflection of the above elements and a strong incentive to do a better data reduction and analysis job. In general, the TEP report review rests primarily upon the technical integrity of the teams and their immediate supervisors, since little other O&M or DCA stimulae is evident.

e. Presence of basic design or implementation errors in the hardware or link.

There are many examples of basic hardware design, manufacturing, or installation defects, slipping through a rather slipshod test and acceptance. Some of these difficulties are too complex to be resolved by the TEP team during a characterization. Many are sufficiently subtile that full isolation is difficult, but the symptoms should be fully documented, and enough special measurements made to absolutely preclude any possibility of test equipment, measurement, or procedural difficulty. The objective should be to clearly identify that a problem exists and bound the issue. The lack of adequate on-site measurement analysis normally precludes any possibility of special measurements, since the lack of data coherence is not found until much later - if found at all. Thus, the basic problem continues to exist, to cause problems uncorrectable by site personnel, and unrecognized by the technical and management structures.

3. Other Impediments

a. TEP measurement schedules are impractical.

The TEP characterizations have to be scheduled by the O&M commands and approved by DCA, the link outage has to be scheduled and cleared worldwide, and the teams and all the instrumentation have to be transported to the often isolated sites. Thus, there are reasons to stick to the prescribed time schedules. The tight schedules could be relaxed, more flexibility in acquiring link outages could be provided, and many other actions taken to permit satisfactory technical completion of the TEP, but all introduce clerical and administrative problems, and this upsets administrators. These actions may increase the expenditure slightly, but a poor TEP is clearly less cost effective than a slightly higher cost for a valid TEP characterization.

b. No minimum standards for TEP measurement and report.

There have been some very poor TEP reports, with tests omitted, measurements obviously in error, data plotted or tabulated with no calibrations or transmission level point recorded, poor to no analysis, and superficial compliance with most major TEP requirements. The DCA and O&M Commands do not vigorously reject these reports and require corrections. Since there is no stigma for the submission of a poor report, and little recognition for a superior one, there is not much incentive to do the job well - except for that personal internal drive that modivates some individuals to always do a good job. This does not include all TEP personnel.

c. No feedback to the field on measurement and report utility.

The lack of specific feedback to the field, tends to support the feeling of TEP personnel that little use is made of the data. Thus with no visible use for all the data, and since this worrisome fact is further substantiated

by 3b above, the inclination of many of the O&M middle management levels is to comply with the letter but ignore the intent of the TEP. Thus, TEP begins to be viewed in the same light as routine administrative command activities, competing for clerical attention.

d. Usefulness suspect since no acknowledged help to O&M or DCA management from TEP.

There is no doubt that most management people see little concrete in the way of outputs from TEP. This, however, reflects their inability to understand system matters. The 10 db and more increase in DCS performance is not seen, the capability of the TEP field experienced engineers to solve problems previously unassailable is not grasped, and the myriad of other benefits have generally remained unnoticed.

Since these present managers see only a few of the benefit to TEP, they give little recognition to the problems uncovered, results obtained, and the contribution of the TEP team members. Thus, it is not surprising that TEP participants are discouraged. All TEP reports without exception, disclose problems. Some are corrected during the evaluation, but the O&M Commands do not move effectively to prevent recurrence. Other degradations are more difficult and require more time, specialized expertise, further measurement or analysis, or application of other resources not available to the team. Follow up by the O&M Command is required. There is no structured way to tabulate and follow up on these frequently ignored remaining problems. The TEP teams wonder whether all the hard work is worth it. The quality (albeit variable) level of TEP reports is attributable nearly solely to the personal integrity of the TEP team members, and not to a management appreciated and nurtured program.

IV. Alternatives

In examining the possible future alternatives for the TEP, many factors must be considered. These include TEP changes to improve the:

a. Identification of system engineering problems.

b. Establishment of DCA System performance standards.

c. Evaluation of the various DCS hardware configurations, classes of equipment and vendors.

d. Evaluation of installation and test and acceptance agencies.

e. Applicability of the data to performance assessment and sensing of DCS performance.

There are four general possibilities that must be examined.

a. Continue the program as it is presently constituted.

b. Modify the program to accommodate the problems described in Chapter III.

c. Kill the program.

d. Restructure the program.

A. Continue the program as it is presently constituted.

There is considerable inertia built into the TEP program, and it would be quite easy to continue as is! The TEP data is far from useless even in its present less than proper form and can provide many useful outputs if the analysis effort were monitored. The cost is questioned by many, but there are a number of DCS gains that can be quoted to justify the expenditures. See Appendix I. There is little doubt that the O&M Commands value the program, and are supporting the effort, although their prime use is clearly in a logistic and operational support role.

The data in the appendix applies directly to the improved performance of the DCS and singular service networks. Programs such as the Autosevocom Evaluation Effort, the Mystic Star Assessment, and the present Autovon TEP and other similar measurement and evaluation programs could not have been even

attempted without the corps of engineers and technicians trained in the systems approached by the TEP. There certainly should be more of these system oriented characterizations in the future. As the DCA attempts to activate a digital backbone, supporting a basically analog structure, system problems will abound. As the DCS tries to upgrade and integrate the performance of the Autosevocom, and Autodin networks, the TEP training is a prerequisite to success.

An operational concept and procedure for the analysis of the present TEP reports has been prepared under this contract. It is clear that much of the TEP specified data is not mandatory, but considerable amounts of the data could provide an insight into the DCS hardware impediments and other matters that are amenable to engineering solution, and would be useful for background studies.

Conclusion

There is considerable merit to continuing the TEP program. The long list of issues briefly discussed in Chapter III, however, give pause to the idea that the TEP should be continued as presently constituted. Clearly, other alternatives must be examined and as will be covered later, this continuation "as is" alternative is rejected.

B. Modify the program to accommodate the problems described in Chapter III

Although the TEP program has continued uninterrupted since April, 1968, there have been improvements, additions, and modifications to the procedures. Many of these changes are known to DCA. There have been other changes unique to the O&M Commands in an attempt to improve the quality and benefits of TEP. Over the years, the DOD has made some progress toward an accommodation with the Chapter III problems. There certainly can be more improvements, and left alone, there will be some. However, the intuitive feeling remains widespread that these changes cannot fully solve the problems.

The following paragraphs discuss possible rapprochement between the TEP and the key problems. All paragraphs refer to the Discussion of Impediments portion of Chapter III.

1. a. In an attempt to raise the performance level of the link hardware, special maintenance teams have been sent to the sites prior to the arrival of the TEP teams. The concept was a good one, and improved hardware condition resulted. In spite of the prealignment, the teams still characterized equipment at less than T.O. standards. There are several reasons for this. The special maintenance teams generally are not systems oriented and each member works to optimize his box or a limited group of boxes and fails to consider the integrated link. These teams do not have all the full instrumentation and so do not run link NPR tests, and do not really place the hardware in TEP ready condition. Further, the DOD fascination with the small theoretical performance gains of space diversity over frequency, cause the selection of space diversity, and so preclude the capability to test the link with no operational disruption. Thus, the small theoretical gain is lost and very large operational degradations result. Also, the frequency density problem has caused many foreign governments to deny frequency diversity applications. Adequate link authorized outages are not always provided, and many key tests cannot be run. If the outage were provided, there would be little difference between the special maintenance and the TEP. Thus, this approach tends toward just more of the TEP, and is too expensive, even if sufficient qualified personnel could be provided.

Thus, the basic problem still remains - substandard hardware.

b. There is no reason why the interconnecting cables and other devices cannot be directly measured, except that baseband cables, and those associated with the radio, all carry the mission traffic. Thus, all measurements disrupt operational signals and have to be accomplished during an authorized link down period. In general, however, provisions could be made, or already exist, to monitor the interface performance once basic and acceptable status is achieved.

c. There is little likelihood that the experience level of the TEP teams will improve. The continuing pressure to reduce costs has forced the services to rely on younger, less experienced officers, and to give command responsibility to younger, non-technically qualified personnel, and rotation through the TEP team is rapid. These steps indicate that any attempts to increase both the numbers and the quality of an elite corps of TEP personnel are not likely to succeed. Also, analytical prowess does not directly follow the issuance of an engineering degree, and the ability to test and align/repair is not taught in most schools - experience is the teacher. The service schools are also downgrading practical instrumentation and lab experience. The overpowering military concentration on "management" has even further reduced the likelihood of engineers acquiring the necessary experience. They are taught to focus on administrative matters - often equated to policy. Thus, the team technical capability is not likely to improve and may get worse.

d. The status of the hardware is not likely to improve greatly prior to the arrival of the TEP team, and the experience and technical prowess of the teams themselves is not likely to improve. The structured TEP Analysis procedures (TEPAP) will give an easier way for the teams to check their data on site, and thus at least get internally consistent information that can be further analyzed at a later date. The analysis will also show where problems remain, so that additional measurements may be made. The 'Scope Creek' schools must increase the scope of the training, and stress on site analysis and fault isolation. The factors of degraded and unstable equipment, however, will continue to impede the TEP teams.

e. The problem of establishing goals for specific TEP report outputs is solvable, and recommendations were made in the TEP Analysis Procedures (TEPAP) submitted as a deliverable on another portion of this contract.

2. a. The problem of inability to repair the hardware because of lack of parts, can be attacked several ways. More parts can be provided when the TEP teams arrive on site, parts can be hand carried as they are needed from any available source, or they can be borrowed from neighboring sites. All of these apparently easy solutions work well on microwave links easily accessable by good roads; assuming management is competent. The approach is less tractable where the site is isolated and where transportation is available only once or twice a week. Further, many parts needed are depot only items and delivery 'NORS rated' may still be much too late to meet TEP needs. This problem can be ameliorated, but not solved. It is an important issue, but one not basic to the general acceptability of TEP.

b. The continued discovering of residual major errors and voids in the Tech Orders many years after arrival of the hardware in the field is a very disconcerting fact. It discloses that, the maintenance and operation of the hardware could not possibly be proper (if additional rationale beyond TEP is needed), and that years of highly structured logistic support fails to identify, locate, or correct the problems. The TEP has been modified, at least within the Air Force, to formalize the responsibilities of the TEP teams to be sure that any surfaced T.O. errors are documented. Even when brought to the attention of the logistic commands, there is tremendous opposition to changes based upon lack of technical competence, blind insistance that it worked alright until now, to refusal based on the cost to change all the tons of paper concerned, just to achieve a "10 db performance gain!"

Certainly continued pressure can bring a slow accommodation by the logistic people. This is a hard issue, however, and changing the logistic point of view from one of "fix after box break" to repair and align all boxes for like new system performance will be very difficult. The service training schools, in general, do not even address such system thinking.

The only way to really address the logistic massive inertia and unresponsiveness, is to perform such an in depth test and acceptance that all hardware defects, and Tech Order mistakes and voids are corrected prior to field use. The logistic immobility then can work to preclude improper later ill considered changes from the field.

c. The lack of test equipment is easy to overcome several ways. All involve money, thus, are a part of the larger question as to the usefulness of the entire TEP program.

The exception to this easy solution concerns the problems of waveguide structures, antenna condition,and aiming. These RF structures all require special test equipment, special training for analysis of measurement results, and entail climbing high towers - a matter not to everyones liking and against military regulations for most personnel. Nevertheless, the RF structure will have to be addressed one way or another once the basic TEP question is resolved.

d. Given no change by DCA, the O&M Command review and analysis of the TEP reports is unlikely to improve, and the quality of the basic report will continue as they are, and the problems discussed above in 1.d., will remain. DCA might provide or contract for some knowledgeable personnel for the TEP report analysis program. Such analysis done by contract earlier was poor and by rote, and the technical grasp of the basic problems was unenlightened. Average of averages type ratings were presented, that obscured nearly every fact of real relevance. This might be avoided, if competent field test engineers and experienced design personnel were employed, but DOD procurement officers tend to buy the lowest cost proposed and this will assure failure as it did before.

3\. a. The problem of adjusting the TEP schedule to fit the maintenance, logistic, and testing load of each link is possible. The transportation difficulties, the interlocking issues of making all of the TEP characterizations on the required every 3 year basis will be impacted. The issue that has often been overlooked by many people who support the TEP in a staff role, is that the TEP goal is a valid characterization of the link not the completion of a report in two weeks.

b. Feedback to the field is dependent upon a number of factors. It certainly presupposes:

1) the conduct of a valid and reasonably complete link characterization,
2) a logical and in-depth analysis of the TEP report,
3) a higher order analysis to extract from the assembled larger body of TEP data, that information, data not easily available from each individual report in isolation.
4) the formalization of conclusions from the basic and higher order studies for use at any level and in sufficient clarity so that the working TEP team members and site personnel will understand the necessity for the added care and effort to assure valid TEP data.

Based upon the logic above in this Chapter IV, B section, it is not likely that these four criteria will be met without some unlikely changes in both the O&M and DCA organizations.

Conclusion

As discussed in sections Chapter IV, A and B, there is considerable merit to continuing the TEP program. The fact that many of the impediments to a smooth flowing and full and accurate link characterization have been attacked with less than full and happy results, and the unambiguous evidence that the military budget and manpower environment are becoming more constrained and in some aspects hostile, clearly mediate against the alternative of relatively routine modifications.

C. Kill the Program.

The logic to defend a program with the manifold problems discussed above, is more difficult than to find fault, and expose troublesome issues. One of the starting points for a possible defense must be to examine the results to date in light of the original goals as stated when the program was initiated and as quoted in the Introduction.

Viewing TEP in light of the original goals, is a somewhat broader vista than the objective presently stated in the contract work statement - "Analysis of the (TEP) data to determine its applicability to system engineering problems." This narrower question still is a valid one and one that must be answered, not just for contract compliance reasons but because of the DCA sponsorship and DOD budget defense reasons. It is a possible alternative that TEP could be dropped by DCA but continued and supported by the O&M Commands. This is a very poor solution, but it does help put the two goals in perspective.

Probably the most productive published output of the TEP program is the 'Blue Book,' so called because the first issue was bound inside Blue covers. This book was, as the result of a directive by HQAFCS in 1972, to meet certain O&M and DCA needs for information. The first document was published in Europe in May, 1973. The European book was reissued in June, 1975. The Pacific area never was able to comply, and the Army and Navy were never asked to do so by DCA. Nevertheless, the 'Command Analysis

of the ECA Wideband System' demonstrates what can be done even in the early years of TEP. Further, it forms the data base against which much other data can be compared, and as a basis for coherent and thoughtful examination of the considerable bulk of other reports now flowing to DCA. This reason alone could save several times the TEP cost - if the unreliable, irrational, non germain, misleading reports were killed and all documents impossible of proper accomplishment, were killed or redone. These reports include logistic, operational, traffic status, etc. These data actually are worse in accuracy and have less meaningful content and are less reducable than the TEP data. There is no large scale management unhappiness with this mammoth waste only because these DCA and O&M separate reports have no way to be checked internally for consistency. Every attempt by the author to cross relate the DCA and O&M report data, has produced results far less coherent than TEP and only grossly related if related at all to the real life DCS status. These reports should be subjected to the same sort of examination as this TEP Evaluation, to assess whether the data submitted can be made to illuminate or even relate to the "need" that generated the report creation.

Conclusion

The data covered in the Appendix listing of benefits derived from TEP, the new analysis concept to be provided as an output of this contract, the workable approach to reformulate and reduce the TEP team workload, the capability to create a viable data base for use in conjunction with the analysis and use of other report data and many other reasons developed in the next section lead to the absolute rejection of this approach to kill the program.

D. Restructure the Program

Since there are only four general alternatives possible, since three have already been rejected, and since this report is going to accept one alternative, clearly this alternative is the one selected.

The DCEC contract work statement gives a more restrictive goal for TEP than was stated when the program was established, yet the phrase "developing and analyzing the issues, and identify those that are applicable to short term or long term (DCS) improvements or upgrade" is surely broad enough to cover most data of interest. The only restrictive phrase is "applicability to system engineering problems." Thus excluded are contributions solely for operations or maintenance and measurements such as the PMP assessing the channel, link, a network operation in normal or stressed conditions, even though these programs had their genesis in the TEP effort, and give substantive technical data. Not excluded, however, is the anlysis and compilation of TEP data on radios or other pieces of hardware, classes of equipment, interconnect cabling, or other information adversely effecting the real life DCS day-by-day operation and DCS design and engineering standards.

1. TEP Goals

What should be appropriate goals for a restructured TEP? Clearly the broad goal is to support the System Engineering of the DCS. This objective is too all-encompassing, however, for precise analysis and examination of the appropriate future course for the TEP. Therefore, a more specific enumeration of proper goals is stated below. These goals are divided into four general categories, and cover the application of TEP to the following:

a. Test and Acceptance of a newly installed link, or one that has had a major overbuild.
b. Characterization of an operational link.
    (1) Never assessed previously.
    (2) An extended period after a previous characterization.
c. Operational evaluation of a link.
d. Assessment of a troubled link.

Clearly the same four goals apply equally well to other elements of the DCS, in addition to links. These include the tail circuits and the base cable plants and installations - all part of the backbone structure. Also encompassed are the three basic DCS networks and the many special networks and their sub-elements, such as terminals, switches, and interfacing and peripheral devices.

This study has examined only the wideband elements TEP, since the other TEP procedures are not yet well developed and little data is available. A similar approach can obviously be applied to all TEP concerns with considerable potential gain, since the organizational structure that created TEP with all its problems is the same one formulating the other TEP's.

2. Restructured Concept

It is obvious that each of the four specific goals is significantly different in its objective from the original TEP, also the number of tests, the depth of the analysis, and the type of report resulting from the four assessments, will vary widely.

a. The Test and Acceptance TEP version is the proper classical use for TEP. It should characterize the link, and analyze the data in the manner described in the "TEP Analysis Procedures" report. This report assesses and proves the performance of the:

(1) RF related structure and propagation path.

(2) Transmitter and receiver.

(3) Multiplex.

(4) Interface, cables, connectors and jack fields.

(5) End-to-end link/channel performance.

It is quite obvious that the most detailed and in-depth TEP is required for a newly installed link. There is no data base of performance information, and both contractor hardware design and installation suitability questions, overlay the questions of the adequacy of the link engineering. Consequently, all aspects of the link must be assessed, and the performance of all elements must be verified. At the conclusion of the Test and Acceptance TEP, a complete measurement data base exists as a standard for all five major link elements as enumerated above, and also for all hardware and cable portions and for use as the 'like new' standard for TEP, and for later reference as link degradation accumulates.

It is self-evident, that no link can be intelligently declared fully operational until a T&A TEP is complete and the measurement data proved internally consistant using the TEP Analysis Procedure.

b. The characterization of an operational link is quite similar to a. above, except that considerable data already should be available from PMP, etc., and a much shortened TEP should be possible.

For example, both transmitters and all receivers need not to be repaired and aligned to validate the link and propagation path. Return loss measurements on the IF module, or combiner, etc., should already have been made at a hardware or link T&A. If the five key elements in 2 a. above are derived and internally consistent, little more need be

done. If some element fails to prove acceptable, then additional TEP data or some O&M type data will be required. DCA needs to know when a class of hardware is chronically defective, hard to maintain, or difficult to align, so that TEP link/system engineers may accommodate the problem, or a product improvement effort can be completed, or management attention can be addressed to improved O&M.

It is to be noted, that every box that produces T.O. standard meter readings, does not necessarily integrate properly, nor operate effectively in a total system environment, and interfaces are not always correct nor noise free. Surfacing long standing T.O. voids and errors is a valid output of this and the T&A TEP.

c. The operational evaluation of a link, as routinely conducted by DCA overseas Areas, should be a stripped down version of a TEP, and can provide in-service NPR and other key parameters to assess how well the link performance and operational requirements are being met. It is obvious that any DCA evaluation should be made in such a manner that measurement results can be directly compared to any other version of a TEP. It is particularly important that the Test and Acceptance and DCA Operational Evaluations correlate with O&M Agency measurements. Since the present TEP - approximately the a. version above - is widely recognized and accepted as the final technical word by all services it is clearly the basis for uniform DCA and O&M assessments.

d. The assessment of a troubled link, can be a single service, a joint service, or a joint service/DCA action. The approach and depth of the TEP will depend upon the a priori data, O&M measurements, or PMP information available. The degree of detail can vary in this type of assessment between full DCA TEP to assure that the link engineering of the path is acceptable or an O&M TEP to isolate a particular problem and return the link to 'like new' performance levels. The manner of measurement must assure, that readings taken by the O&M Agency can be directly compared against the TEP isolation test results, and also against any previous Test and Acceptance or other full link characterization. Unless this mutuality is achieved, there will be conflict and lack of resolution to problems that should be straightforward to correct.

e. There is a fifth category of TEP, that is normally restricted to O&M usage. This TEP includes the periodic assessment of links much as is done presently. It includes the maintenance assist efforts when PMP, IG or other event triggers an O&M corrective fault isolation or assistance effort. None of these activities relate directly to DCA, but it is obviously highly beneficial if all measurement approaches, test instruments, and test procedures are standardized throughout. Thus, assessments, or test measurements made by a maintenance assist team can be usable, by D&A to fill a void in system engineering or equipment related data, or by another military

department with responsibilities for the other end of the measured link. It does not make sense to permit 'pure' DCA or 'unique' O&M dissimilar measurement approaches. Thus, this fifth goal, is a natural and obvious, fall-out from the four DCA goals, and is a determining vector in deciding the final recommendations.

3. Restructured Approach

a. A review of the DCA Circular 310-70-57 DCS Quality Assurance Program reveals three major subdivisions:

1. Technical Evaluation with the objectives to "collect performance and design data; to improve operational, maintenance and engineering criteria; and to develop a data base of operational characteristics and deterioration patterns for the DCS."

2. Performance Monitoring with the objectives to "identify critical operating parameters that identify degrading links and networks; and to establish management and performance standards to facilitate timely corrective actions.

3. Performance Evaluations - normally referred to by the field as Ops. Evals. - "to evaluate facilities, to identify significant deficiencies and problem areas; to present these problems to management, to ensure that the problems are resolved."

Although not stated expressly, it seems evident that the test procedures in 310-70-57, were intended to be used by all personnel who perform any of the above Quality Assurance Programs. As such, it is self-evident that the widely differing technical needs, and the diverse operational objectives, mediate against a single test complement. Clearly, if a troubled link has problems in the antenna and propagation path, there is no need for tests related to the multiplex. Thus, a scaling of the number of tests for each of the four classes of problems is required, but until the TEP Analysis Procedures and Operational Concept report by this author, (TEPAP) no specific basis for resolution of this question was available. Thus, this report was used as the basis for the below Restructured TEP Approach. Figure 1-1, from the TEPAP report show the five elements of a link that are examined, and Table 2-1, lists the only data that is needed to complete the link engineering validation. Since one of the prime reasons for this study in the first place, was the desire to reduce the cost of a TEP, there is strong logic to delete all unnecessary testing. In prior years, 'unnecessary' was a hard term to define. The TEP Analysis Procedures have, however, given an absolute way to differentiate between required and desirable - put another way, mandatory or supportive.

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T.E.P. LINK CHARACTERIZATION

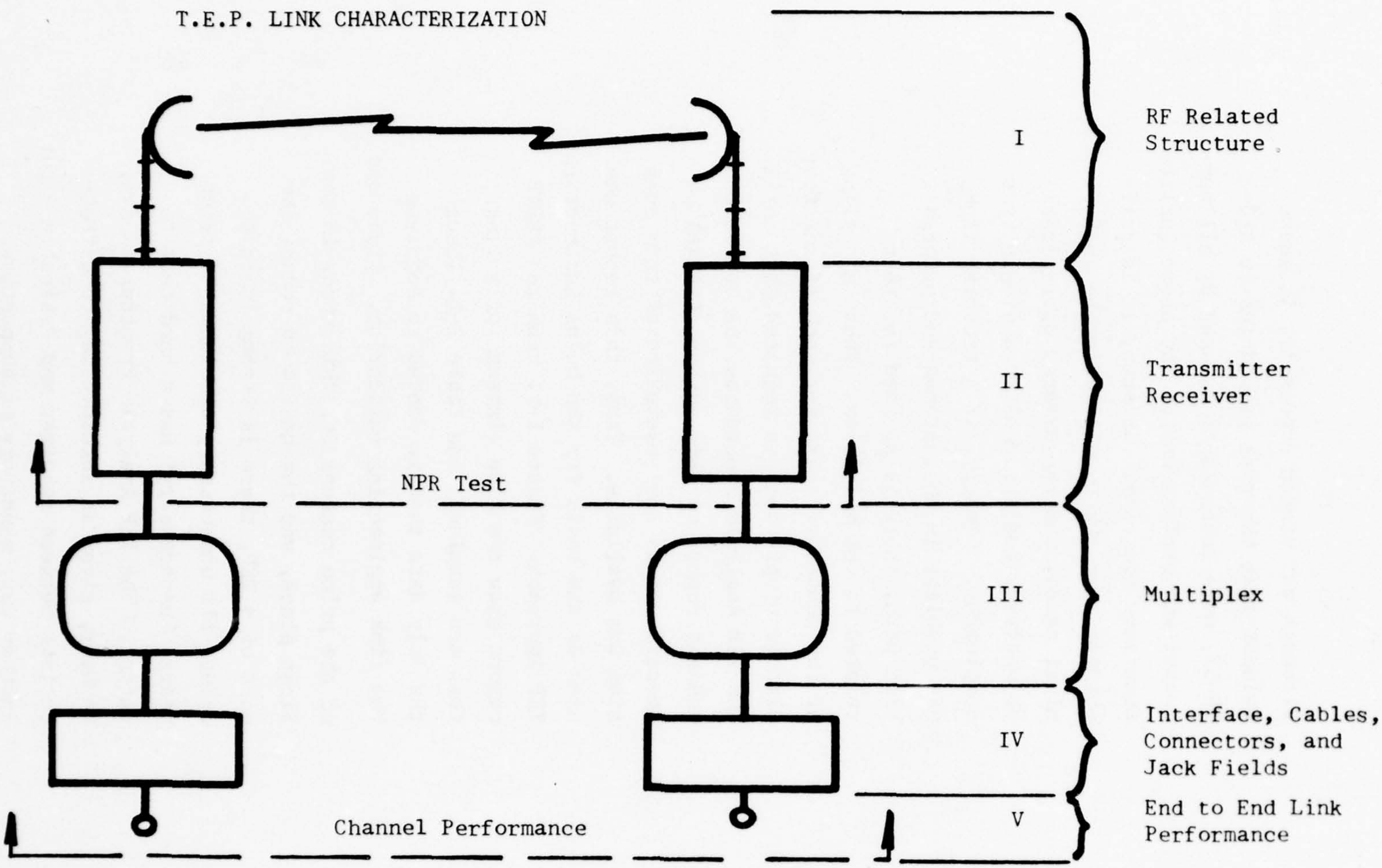


Fig. 1-1

TEP Report # ____________ DCA Link # ____________ PMP Link # ____________ Dated ____________

Element		Item	Calculated Value	Link ______ A	B	______ A	B
Receiver		Noise Figure					
		IF Bandwidth					
		FM Threshold					
		Per Channel Deviation					
		Pre-emphasis					
		Frequency Slots					
		Fully Quieted					
Receiver and Transmitter		NPR (loop)					
		BINR (loop)					
Multiplex		NPR (loop)					
		BINR (loop)					
System		Number of Channels					
		Receive Signal Level					
		NPR (link)					
		BINR (link)					
		Channel Load Factor					
End to End Channel Performance		Baseband Loading					
		Idle Channel Noise (3 KHz)					
		Idle Channel Noise (C msg)					

Table 2 - 1

The listing of required TEP tests is given below, but a discussion may help explain the drastic reduction in required tests. TEP has a specific Noise Figure test. It is not necessary, however, to perform this noise figure test if a full receiver quieting curve is run and is proper. There are many other tests that similarly and directly measure parameters that are indirectly assessed by another test. Thus, it is possible to restructure the TEP to provide all the data required at a very large saving in time, test equipment, data gathering and resultant expense.

If the results of a particular basic test are not acceptable, a second eschelon of additional tests are needed to characterize the problem in more detail, or to directly assess the degraded element. These additional tests are supportive and are not needed for link validation. They are not - in accountants parlance - chargable to DCA, but rather are an O&M cost.

All references to test procedures, and the test reference numbers relate to DCA 310-70-57, Supplement 1 dated October, 1974.

The normal link engineering assessment and path validation can be performed based upon only six tests - one of them run twice for 'as found' status data. Test (T-9) is incorporated in test T-1. These tests are:

1. T-1 Multiple Parameter Data Recordings
2. T-34 RF Receiver Input Power, vs. AGC, FM Receiver Noise Quieting, (Balance of test not needed)

3. T-22 Radio Equipment NPR/BINR loop

4. T-23 Radio Equipment NPR/BINR link

5. T-40 Multiplex NPR/BINR

6. T-8 Idle Channel Noise - manual measurement

7. T-1 Multiple Data Recordings

b. Each test is used to extract selected data needed to fill in Table 2-1.

4. Restructured Approach Evaluation

Now that a new restructured approach has been posed, it is appropriate to examine the impediments that kept the present TEP from meeting all its original goals, to be sure that all have been accommodated.

a. Basic Impediments

III B 1a. Equipment not aligned.

b. Equipment not operated correctly.

c. Interconnecting cabling not noise free.

d. Teams unable to repair link.

This problem can be avoided under the new approach. The ICN vs. baseband loading vs. NPR curve can be used to assure that the link is at or near proper alignment. The TEP teams can be scheduled only when near proper link operation offers high likelihood of successful completion of the repair, alignment and characterization.

The fifth basic impediment is:

III B 1e. On-site analysis inadequate.

The new TEP Analysis is conducted as the restructured TEP progresses, and the errors are evident. The ICN vs. BBL vs. NPR curve allows full correlation of data prior to departing the site.

The last basic impediment is:

III B 1F. No established goals for specific TEP outputs.

The section of this report lists in IV 8, a set of specific output products, some of which can be prepared prior to TEP team deployment and IV 8b, is prepared on site for preliminary assessment, and with more refinement back at HQ. Further, the ICN vs. BBL vs. NPR curve is plotted and work continued until acceptable results are obtained. These six products, alone, are a significant step up from the present bulk book issuance. Failure of the end-to-end TEP data to plot acceptably on the ICN vs. BBL vs. NPR curve is the basis for rejection of the TEP report data and for re-accomplishment of appropriate portions. If the three parameter curve does not check at normal load and also at CCIR loading within $\pm$ 2 db, the TEP is unacceptable.

The annual issuance - or update - of the Blue Book has established: Region, Area, Command and DCS goals of both performance and inferred objectives for management.

The $\pm$ 2 db end-to-end performance check in order to be 'acceptable' and the standard products establish goals for both the TEP and the DCS that all can recognize.

b. Important Impediments

The important impediments are discussed in order of their appearance in III B2.

a. Teams unable to repair equipment due to lack of parts.

There is no full cure for this, but the requirement for 'somewhere near' proper alignment prior to the initiation of the TEP, will solve the bulk of the difficulties prior to the arrival of the teams.

b. and e. Tech. Order errors/Design flaws.

Since the new TEP Analysis Concept permits 'closing' the calculations and proving validity of the basic measurements, failure to achieve such proof is basis for re-examining the various portions of the analytical test data. Any inability to correct problems is basis for questioning the T.O. procedures, the hardware design, or the installation engineering. The TEP report submission thus must await the resolution and isolation of the basic cause. Thus, a 'held for further analysis' TEP report is a good management alert to a major problem.

c. Lack of key test equipment.

The necessity for much less test equipment for the restructured basic TEP tests greatly reduces the likelihood of failure by permitting duplication without excessive cost or weight and space problems.

d. O&M Command TEP report review inadequate.

The section that describes the TEP output products, will produce the first field visible and field usable outputs, even if the O&M and DCA HQ's fail to perform at all. A program of defective hardware

identification based upon TEP followed by overt product improvement, should do much to focus the O&M goals and give honest credence to the command stated verbage "to support the field."

c. Other Impediments

The remaining impediments are discussed, again in order of their appearance in III B3.

a. TEP Measurement schedule impractical.

Since the TEP teams will be launched only when links are 'somewhere near' acceptable, the adherence to the on-site schedule should be much more nearly achievable. It is possible that some scheduled TEP measurements may be delayed prior to team deployment because of various link technical problems. This will undoubtedly upset administrative people, but the cost is only a bit more paper work and no real lost manpower,intensive TEP activity, and no travel associated expenses.

b. No minimum standards for TEP measurement and reports.

Covered in several of the above sections.

c. No feedback to field and lack of utility.

Covered in above comments.

d. O&M and DCA acknowledge little help from TEP.

The issuance of a Blue Book, and establishment of a routine follow-up corrective action schedule followed by an update page for the Blue Book giving

the corrected performance would go far to persuade field personnel that the long Christmas tree sequence of HQ's in fact do care about the field, and that mission performance - not reporting - is the command goal.

5. Specific Testing Framework

I. First Basic TEP Measurement - This first measurement is composed of:

Test T-1 Parameter Data Recording provides:

(a) ICN 3 KHz

(b) ICN C Msg

(c) Phase jitter

(d) Impulse noise (T-9 added to T-1)

(e) Baseband loading

(f) Receive signal level (single receiver) for the link

Test T-8 Idle channel noise provides:

(a) ICN 3 KHz across the baseband

(b) ICN C Msg across the baseband

(c) Cable noise

(d) Cable crosstalk

(e) R.F.I.

(validates T-1 single channel recording data)

These tests provide an improved 'normal operational status,' as found upon arrival on site.

"Improved" normal conditions because the maintenance actions required to return the link to nearly like new have been accomplished.

This test run with no advanced maintenance should closely approximate the PMP recorded data.

II. Second Basic TEP Measurement

T-34 Quieting curve provides:

(a) FM threshold

(b) Fully quieted receiver noise

(c) De-emphasis

and validates pre-calculated

(a) IF bandwidth

(b) Noise Figure

that is, if the receiver quieting curve is proper, the IF bandwidth and noise figure must be correct. Compensating errors can be hypothesized, but these errors are disclosed in later tests, such as NPR. If the results are not acceptable, perform one or more of the following:

T-36 Noise figure

T-39 IF bandwidth

T-35 RF/Preselector bandwidth

T-24 Pre-de-emphasis

and hardware maintenance as required.

Re-accomplish T-34.

III. Third Basic TEP Measurement

T-22 NPR/BINR loop provides:

(a) Receiver fully quieted basic noise

(b) Transmitter basic noise

(c) Receiver intermodulation noise

(d) Transmitter intermodulation noise

If the results are not acceptable, perform one or more of the following:

T-39 IF bandwidth, shape, and centering
Discriminator curve (very important)

T-29 Transmitter linearity
Transmitter frequency deviation

T-25 Radio frequency interference and spurious

T-26 Transmitter-receiver isolation

T-31 Transmitter bandwidth

and hardware maintenance as required

Re-accomplish T-22.

IV. Fourth Basic TEP Measurement

T-23 NPR/BINR link provides:

(a) Path noise

(b) Path Intermodulation

If the results are not acceptable, perform the following:

T-25 Radio frequency interference and spurious

T-26 Transmitter-receiver isolation

T-32 Frequency swept VSWR

T-27 Transmitter frequency accuracy

T-28 Transmitter automatic frequency control and hardware maintenance as required

Re-accomplish T-23.

V. Fifth Basic TEP Measurement

T-40 NPR/BINR Multiplex
(a) Mux basic noise
(b) Mux intermodulation noise (delete after standard mux characterization)

If the results are not acceptable, perform the following:

T-14 Harmonic distortion noise

T-21 Intermodulation, channel

T-16 Phase jitter

T-9 Impulse noise

T-3 or 4 Multiplex level integrity

and hardware maintenance as required.

Re-accomplish T-40.

Note: a. The mux loop test must use <u>both</u> the transmit and receive baseband cables in series with the shield grounded at the junction.

b. All measurements must be made at the equal level boatd - or at the normal patch field, not at the mux.

VI. Sixth Basic TEP Measurement

T-1 Parameter Data Recording provides:

(a) ICN 3 KHz
(b) ICN C Msg.
(c) Phase jitter
(d) Impulse noise (T-9 added to T-1)
(e) Baseband loading
(f) Receive Signal level

T-8 Idle channel noise provides:

(a) ICN 3 KHz across the baseband
(b) ICN C Msg. across the baseband
(c) Cable Noise
(d) Cable crosstalk
(e) RFI

If the results are not acceptable, perform the following:

T-3 Customer signal level
T-18 Channel crosstalk (Test in-service)
T-7 Channel balance
T-41 Alarm and Pilot Operation
T-15 Frequency translation
T-8 Idle channel noise - expanded to more channels
T-X New test for audio and baseband cables

and hardware maintenance as required.

Re-accomplish T-1 and T-8.

The inability to achieve proper results on all six basic tests precludes submission of an acceptable TEP report. O&M support or other activity must be accomplished and the defective tests, and T-1/T-8, re-accomplished.

The TEP tests thus categorize as follows:

Test	Basic	Analytical	Possibly Supportive	Not Useful
T-1	x			
T-2			x	
T-3		x) combined with		
T-4		) sampling and selective voltmeter		
T-5			x	
T-6			x	
T-7		x		
T-8	x	x (expanded)		
T-9 (added to T-1)		x		
T-10			x	
T-11			x	
T-12			x	
T-13			x	
T-14		x		
T-15		x		
T-16		x		
T-17		x		
T-18		x		
T-19				x
T-20				x
T-21 (Specify at least one transmitter and two receivers)		x		
T-22	x (or two transmitters and one receiver - to pass)			
T-23	x (Same note as T-22)			
T-24		x		
T-25		x		

Test	Basic	Analytical	Possibly Supportive	Not Useful
T-26		x		
T-27		x		
T-28		x		
T-29		x		
T-30		x		
T-31		x		
T-32		x		
T-33			x	
T-34	x			
T-35		x	x	
T-36		x	x	
T-37			x	
T-38			x	
T-39		x		
T-40	x			
T-41		x		
T-X		x		

T-X The new test for audio and baseband cables.

6. General Observations

a. The 310-70-57, test procedures are in a number of cases, suitable for subdivision into basic, analytical, and supportive categories. T-34, for example, the quieting curve and AGC voltage is basic, the limiter curve is analytical. Most, but not all, the tests themselves are quite satisfactory, although, no standards are given to cause rejection of test results and to cause hardware or other repair before re-accomplishment of some test. In several cases, for example, T-1, a 3 day test is specified for use after the link is like new - this time is adequate for all of the necessary in-depth site TEP

gathered data analysis. Thus, if the data fails to correlate, additional work can be done prior to reconducting the T-1 test and before departing the site.

b. There are several changes that should be made in the TEP broad guidance, but the magnitude is not large. The T-1 data recording test should be modified to incorporate T-9 (impulse noise) and to include as a part, the cross-correlation of ICN - baseband loading - NPR as described in the TEP Analysis Procedures to within $\pm$ 2 db. Failure to do so, is reason to reject the TEP report.

Note: All of the foregoing has been keyed to microwave. It will be helpful, or at least simplifying to separate the tropo procedures from the microwave for all tests where the approach or procedures are different.

Portions of some tests should be dropped as non-relevant or incapable of analysis application in a meaningful way - such as the distribution of noise in a microwave voice channel. T-19 and 20 data/teletype ber, should be dropped in entirety.

c. T-X Test

There is one additional test that must be added to the present TEP package, or it can be inserted as an expansion to existing test procedures. Test T-25 covers the use of a frequency selective voltmeter and spectrum display unit to examine the baseband. When in the terminated IF loopback mode, the baseband cables are assessed along with the trans-

mitter and receiver elements. If this measurement is quiet - all undesired signals at least 65 db below TLP - there is no problem. However, if signals exceed this threshold, an additional test is required.

A loopback of the baseband cables, grounded first at the transmitter, and then at the receiver, while retaining the normal grounding at the multiplex, will ascertain where the signal intrudes. These tests are made using "T" connectors to preclude disturbing the normal ground loops. It may be necessary to measure each cable selectively grounding the cable at each end and both ends to isolate the RFI entry mechanism.

It will also be necessary in some cases to use the selective voltmeter and display unit on the voice channel cabling. The fact that only 4 KHz of bandwidth is supposed to be present does not prevent signals in the KHz and low MHz bands from pickup and devious entry into the multiplex or baseband.

It is often illuminating to "T" into the ground leads or basic grounding structure and examine the signals, hum, and noise present. Ground leads shared with high antenna towers are always suspect - and normally troublesome. Grounding structures where two prime power frequencies are used are always difficult.

The key point is that a selective voltmeter and spectrum display unit is possibly the most powerful assessment and diagnostic tool for the TEP and site personnel, and RFI intrusion isolation and analysis is one ideal application.

d. Total Quality Assurance Restructuring

There are three additional uses for the 310-70-57 tests. The above detailed analysis differentiated among Basic, Analytical, Possibly supportive, and Not useful. The following categorization is somewhat different.

	FOR MICROWAVE			
	T&A	T.E.P.	Ops. Eval.	Ops. Assist (troubled links and O&M)
T-1	x	x	x	as required
T-2	x			"
T-3			x	"
T-4	x			"
T-5	x			"
T-6	x			
T-7	x			
T-8	x	x	x	
T-9	x	(add to T-1)	(add to T-1)	"
T-10	x			
T-11	x			
T-12	x			
T-13	x			
T-14	x		x	
T-15	x		x	"
T-16	x		x	
T-17				
T-18	x			
T-19	delete			
T-20	delete			
T-21	x		x	"
T-22	x	x		
T-23	x	x		
T-24	x			
T-25	x			
T-26	x			"

	T&A	T.E.P.	Ops. Eval.	Ops. Assist (troubled links and O&M)
T-27	x			as required
T-28	x			"
T-29	x			"
T-30	x			"
T-31	x			"
T-32	x			"
T-33	as required			"
T-34	x	x	x	"
T-35	x			"
T-36	x			"
T-37	x			"
T-38	x			"
T-39	x		x	"
T-40	x	x		"
T-41	x		x	"

(1) Test and Acceptance

The purpose for the T&A, is such that <u>all</u> T series tests should be run to gather link and all relevant sub-element performance to be used as a later reference and maintenance assist. The exceptions are T-19 and 20, and portions of several others that serve no useful purpose - are not capable of being reduced and applied for any functional purpose.

(2) TEP

The TEP 6 tests are as described above.

(3) Performance Evaluations (Ops. Evals)

The following tests should be standard for all this class evaluations:

T-1 Parameter Data Recording

T-8 Idle Channel

T-9 Impulse Noise - (as part of T-1)

T-14 Channel harmonic distortion

T-15 Channel frequency translation

T-16)
)Channel phase jitter
T-17)

T-21 Channel intermodulation

T-34 Quieting curves

T-39 FM discriminator - portion only

T-41 Alarm levels and operation

Thus, the TEP tests can be further divided into four classes, depending upon the five categories discussed in IV D 1a, b, c, and d.

This report has frequently referenced the TEP Analysis Procedures (TEPAP) also developed under this contract, to explain data requirements and analysis concepts. A copy of Table 2-1, from the TEPAP shows how each of the required items is derived in the new streamlined TEP approach described in this report. These items are good and sufficient to validate the link and path engineering, installation, hardware performance and audio-to-audio total link status.

7. Test Equipment and Personnel Impact.

On the assumption that only the basic tests are to be performed, and that the analytical tests are to be conducted by a maintenance team, the TEP test equipment required over and above that on site consists only of the:

a. NPR test set

b. Power meter

c. Signal generator

d. Recorder

TEP Report # ____________ DCA Link # ____________ PMP Link # ____________ Dated ____________

Link ____________ ____________

Element		Item	Test #	Method of Item Derivation
Receiver		Noise Figure	T - 34	Indirectly Observed
		IF Bandwidth	T - 34	Indirectly Observed
		FM Threshold	T - 34	Directly Observed
		Per Channel Deviation	T - 34	Indirectly Observed
		Pre-emphasis	T - 34	(De-emphasis) Directly Observed
		Frequency Slots	T - 34	Directly Observed
		Fully Quieted	T - 34	Directly Observed
Receiver and Transmitter		NPR (loop)	T - 22	Receiver plus Transmitter NPR Directly Observed
		BINR (loop)	T - 22	Receiver and Transmitter Noise Directly Derived
Multiplex		NPR (loop)	T - 40	Directly Observed
		BINR (loop)	T - 40	Directly Observed
System		Number of Channels	---	Directly Observed
		Receive Signal Level	T - 1	Directly Observed
		NPR (link)	T - 23	Path Intermod Indirectly Derived
		BINR (link)	T - 23	Path Noise Directly Derived
		Channel Load Factor	---	Calculated
End to End Channel Performance		Baseband Loading	T - 1	Directly Observed
		Idle Channel Noise (3 KHz)	T - 1 & 8	Directly Observed
		Idle Channel Noise (C msg)	T - 1 & 8	Directly Observed

Table 2 - 1

The six basic tests can be performed by one engineer, two technicians, plus on-site personnel.

It is not suggested that the above be applied without thought, but such an approach does permit several alternative approaches and still produce an effective TEP. For example, the existing TEP teams could be split, to double the number of teams. (More on why this is desirable below). The additional personnel should be provided by the Group and site. The Group would be a logical and likely place to place the saved TEP personnel. The analytical tests should be performed by the site and Group personnel, for training and for on-site recognition of the realized operational status of their hardware - regardless of what fanciful logistic status is reported.

Doubling the number of TEP teams is a highly desirable goal from an operational standpoint. Where an authorized outage (AO) is required, the time and effort is high, administratively to get user approval and technically to establish all needed alt-routes. Two teams can measure one link during one AO. Three teams can measure two links. Thus, the AO cost per link is cut in half. Four teams can measure three links during the one AO. This is obviously considerably more effective than the present link-by-link concept now used. Further, if four teams are in the field concurrently on adjacent links, a team director - an experienced TEP team chief - can afford to be deployed for assistance to troubled teams, for training, for measurement data analysis help, and general technical optimization.

8. TEP Output and Analysis

a. The TEP report, of course, is the first visible output. It includes as a minimum, the six basic test results and the analysis that is appropriate. If any basic test is less than acceptable, the analytical tests conducted to isolate and correct the problem will be included in the report, along with a discussion so that possible hardware, Tech Order, or design problems are surfaced. If the analytical tests fail to resolve the problem, the Tech Order, PMI or other maintenance effort used, to attempt to rectify the difficulty, will be included and discussed even if fruitless. These failed basic tests are really a prime source input to all concerned HQ's of technical/operational problems requiring attack and resolution.

On a good link with good hardware, the ultimate TEP should be the completed basic tests and suitable analysis.

On a poor link or one with bad hardware, the ultimate TEP should be the completed basic tests, with sufficient analytical tests and special isolation measurements to clearly highlight to all levels of management what has to be fixed, or what required repair.

b. The TEP analysis should be accomplished as described in the TEP Analysis Procedures TEPAP report. As part of this activity, a number of standard products should be prepared. The products should be accomplished during the Test and Acceptance phase and made a formal part of the System Tech Order, in spite of the general

logistic structure reluctance or inability to view a box as part of a total system. It must also be done as part of the TEP on any in-place link where these products do not exist. These products must then be integrated into the logistic/maintenance mechanism. (T.O. or PMI).

The products include:

a. LOS Path Calculation

b. Tabulated Extract from the Link Data

c. Standard Quieting Curve

d. Standard AGC Curve

e. ICN vs. Baseband Loading vs. NPR Curve

f. RSL Distribution Curve for the Link.

The curves c, d, and e, are standard for the class of hardware concerned on normal links and are <u>not</u> site compensated. That is a good receiver is a good receiver. The curve e <u>may</u> have to be adapted slightly only if the link has significant propagation anomalies.

c. As mentioned earlier, an analysis complete enough to assure a valid TEP report will be conducted on-site. There will be added refinements, and expanded analysis back at the TEP team home base, along with explanation of significant factors, discussion of data taken using the various needed TEP Analytical tests.

d. The next level of analysis, however, must come at some level within the O&M Agency where a number of TEP reports on similar equipment can be examined in a broader context. If all hardware of a particular type has a poor discriminator, or the front end is quickly

degraded, a product improvement effort may be called for. An improved alignment procedure, different test equipment, or other suitable action may be required to correct an area type problem.

It is suggested that responsibility for each hardware type be assigned to the O&M Agency with the bulk of that equipment in service use. They then could focus their analysis efforts on a smaller set of problems, knowing that someone else would be working on the other hardware.

This HQ analysis clearly is of a higher technical level, and should lead to better results - there will be no need to wrestle with volumnous, inconsistant data such as that normally facing a TEP HQ review team today. No 'sanitizing' to cover technical defects should be used.

There is another product that has been prepared by one Area of the AFCS in response to a HQ AFCS analysis directive. It extended the approach, and added several features that are of value to management. The product is called the 'Blue Book,' although the proper name is 'Command Analysis of the ECA Wideband System.' The latest version - now in brown covers - is dated June 1975. This document includes:

a. A link summary sheet
b. A link map layout with the RSL data plotted
c. A link map layout with the ICN data plotted
d. A sheet describing the known problems with the links.
e. A quieting curve with the ICN and RSL plotted; as measured by the TEP team, as predicted by the path calculations, and as reported by the PMP. (These are not always the same).

All of the O&M Agencies should be required to assemble a 'Blue Book,' generally in accordance with the present Eurcom Area format - after accommodation and modification to the concept covered in the TEP Analysis Procedures. Included should be the Quieting Curve, but also with link performance plotted on the ICN-NPR-baseband loading curves, and several other modifications such as map presentations that are useful to managers.

This above described summary/analysis book from each O&M Agency for each Area would be very useful to both the O&M and DCA managers, and would be a common basis for addressing common problems.

e. The DCA analysis could then focus on two major matters:

   1. Is the link engineering proper - and that should be quite straightforward from the new simplified TEP Analysis approach.
   2. Is there a hardware, interface, or other equipment difficulty that is adversely impacting the DCS in sufficient magnitude to warrant a DCS response.

9. DCA Concomitant Field Actions

One of the major depressants of the TEP program is the doubing view held of TEP results by management and the working level personnel. Managers, as described above fail to understand the data and wonder about the accuracy, usability, etc., and so fail to use the TEP information aggressively in attacking poorly performing links. The people on-site, generally, see no reason to worry about the

defects surfaced by the TEP, or the degraded link operation. Why should they, management does not! Both management and the field normally do react to PMP difficulties, once established thresholds are violated.

The action that would be perhaps most beneficial to the entire DCS would be for DCA management to react quickly and firmly to link degradations. Examples, such as listed below, would be salutory.

a. Direct an immediate Performance Evaluation following any significant link outage.
b. Require a 'hardware' RFO for all one way link outages.
c. Require an immediate receiver quieting and AGC curve, and 15 minute PMP reports through 55-1 during all propagation outages (include ICN and RSL, and baseband loading if any remains.
d. Require an O&M follow-up, and use full TEP including the (TEPAP) Technical Evaluation Program Analysis Program procedures if any of the above required actions indicate significant hardware degradation, or poor operation. The results of these TEP reports should get wide command and DCA distribution - not to point a finger at a bad example, but to show to the DCS that all degradations have a reason, and that intelligent management and energetic maintenance and operator activity can surface and fix a bad link - and so can preclude occurance of such problems.

   In those very, very, few cases where a design defect, or poor link engineering is the cause, the link will be 'exonorated' by the TEP, and management can address the proper corrective action.

   In all cases, the DCS gains in both the short and in the long run.

Appendix I TEP Cost Effectiveness

The cost effectiveness of the TEP has been questioned by many people - but not all. Those people who have a deep technical insight into mission and systems matters have always grasped the broad contribution by TEP to the O&M Activities and the DCS. Those people who concentrate on clerical and adminstrative activities often fail to see the good. There is no question that the lack of uniformly acceptable report analysis and the absence of feedback products (in sufficient paper depth to be impressive) has hurt the TEP program image. Nevertheless, the TEP contribution to the DCS is very sizable.

The analysis to derive the actual TEP value in dollars, is not straightforward, and there is no way to directly calculate some of the benefits. There is, however, a reasonable method to obtain an 'equivalent' cost benefit by assuming that the identical activity had been acquired by contract. There is sufficient experience to estimating costs on a large variety of DCS efforts, so that the 'equivalent' cost estimate method should give a reasonable result. For example, TEP team personnel and test procedures, were used to assess, fault isolate, and derive a fix for a defective microwave radio. The fix was installed in an overseas O&M facility, with the proof of the fix conducted by the TEP personnel. This work could have been done by the radio manufacturer, or by another contractor. The time required, the costs involved, and the documentation activity needed, all are easily convertible to contract dollar equivalence for the TEP portion. The fix installation costs are not attributable to TEP.

In some cases, the simple direct one-for-one conversion cannot be made, so other indirect methods of estimating equivalence is used. In these cases, the conversion approach is briefly described.

The dollar estimates are those of the author, but reflect at least reasonable accuracy. The magnitude of the TEP cost benefits and cost avoidances, however, is so large that even significant estimation errors will not change the obviously highly cost effective nature of the TEP.

It is obvious that the $255,230,000, would not have been spent, since the cost would have been pre-deemed too high. Nevertheless, the general value of benefits have occurred to the DCS by the expenditures for TEP, and most of the benefits related to networks are not yet included.

Further, the benefits for digital transmission are not yet estimatable. If the TEP is not kept current, the new digital DCS may revert to the marginal performing structure that categorized the pre-TEP DCS. The future TEP need not be so large perhaps, the procedures, and analysis can be streamlined and the cost reduced, but TEP clearly is cost effective.

The breakdown of each of the six TEP contribution categories is summarized below, and each grouping is expanded in ensuing pages.

The TEP summarized products and gains would have cost as estimated below.

NOTE: These costs assume contract personnel both competent and experienced enough to do the job immediately. This is a very poor assumption. Most contractors routinely have a 1.5 or 2.0 factor, with the early contracts to build up knowhow and experience. The attempt by DCA to get the TEP reports analyzed is an excellent example of a contractor slow-learning curve, and the reports analysis never was really very effective.

The learning costs are not included in these figures.

	Study	Dev	Field Proof Evaluation	Final Concept	Total
Management	2700	900	5050	1650	51,700
TEP Basic					10,670
System	600		6500	100	120,210*
Tech/Eng	3000		11,750		61,250
O&M/DCS	500	250	900	300	1,950
Other TEP	2200		4750	750	6,700
	9000	1150	28,950	2800	252,480*

All costs in 1,000's of dollars
* 55,000,000 is cost avoidance

A. TEP Management Gains

(A). Proved the 'fix <u>before</u> failure' concept.

(B). Established basis for technical mission assessment and management. (PMP and Network assessment)

(C). Created mechanism permitting de-centralized execution (Group) but centralized management.

(D). Established basis for resolving inter-service problems.

(E). Made technical terms intelligible to management. (ICN, base-band loading, db, etc.) (equivalent to 3 weeks of school for 2000 managers)

(F). Made technical mission matters understandable to management. (a sub-element of E above)

(G). Surfaced many system matters.(vs box problems)

(H). Created a management approach applicable to O&M contract operations. (PMP + TEP)

(I). Created a management approach applicable to leased channels and groups.

(J). Created basis for evaluation of Service O&M performance.

(K). Proved to management and field technicians that much of "what was known" was false. (Propagation,'other end' syndrome, etc.) (education = 4 weeks)

(L). Proved the concept of 'product improvement' vs replacement - (Philco LC series radios, and REL tropo) and provided the basis for selecting hardware for improvement.

(M). Provides basis for valid technical evaluation of competing hardware vs the previous choice on initial cost alone.

(N). Provides the data upon which to base a valid cost effective investment strategy.

A. TEP Management Gains

Had the expenditure been as indicated below, the estimated cost would have been:

	Study	Development	Field Test Evaluation	Final Concept and Application Paper	Total
(A)	100		750	100	950
(B) PMP	500	400	500	250	1650
Nets	1000	500	1000	500	3000
(C)	200		300	100	600
(D)	included in B and C above				
(E)	$2000/mgr x 2000 mgrs + continuing				4000
(F)	included in E above				
(G)			2000	400	2400
(H)	200			100	300
	actual use benefits				400
(I)	100			100	200
(J)	included above				
(K)	1700/man x 10,000 tech men and mgr and continuing				*17,000
(L)	400		500	100	1000
	including examples REL Tropo - redo of Philco LC series radios				20,000
(M)	included above				
(N)	200				200
	2700	900	5050	1650	51,700

* see AFCS study

B. TEP DCS System Gains

(A) More than 10 db (order of magnitude) performance gains in DCS wideband.

(B) Permitted successful operational utilization of Autovon.

(C) Contributed to successful operation of channel packing.

(D) Permitted operationally useful utilization of Mystic Star.

(E) Provided intelligent basis for converting to more unmanned sites.

(F) Provided basis for real time power control for tropo links.

(G) Proved that the operational capability for secure voice could not be met in Mystic Star.

(H) Provided basis for greatly improved personnel utilization, (maintenance, operations, and management) and lower skills many places.

(I) Killed digital Weather Facsimile development/production program.

(J) Permitted correction of several design defects in Collins standard MW before DCS acceptance.

(K) Permitted identification of a number of design errors and manufacturing defects in the Philco LC series microwave radios for correction by the services.

B. System Gains

The equivalent costs to achieve the TEP gains by contract are estimated to be:

	System	Dev.	Field test Evaluation	Final Concept and Application Paper	Total
(A)	(Cost avoidance)				40,000 (avoidance)
(B)	Cost of hardware and avoidance				15,000 (avoidance)
(C)	13 x 1200/yr x 3 years / ¼ to TEP				11,700
(D)	400		1500	100	1,900
(E)	10 men/site x 40 sites x 3 years x 20k/man				24,000
(F)	7 KW x eff x 8 mo x 20 sites (10 links)				(1) 160
(G)	covered in mgt. except equipment savings				250
(H)	maintenance eff increase 20% x 5000 x 20k/man				20,000
(I)	200 saved poor equipment problems		5000		5,200 2,000
(J)	included in Management L				
(K)	included in Management L				
	600		6500	100	120,210*

*55,000 cost avoidance

(1) 10k btu/kwhr x 7 kw = 70,000 btu/7kwhr. x 2/link = 140,000 btu/7kwhr link ≅ 1 gal diesel fuel/hr

$\frac{1\text{gal}}{\text{hr}}\ \frac{20\text{hr}}{\text{link}} = \frac{20\text{ gal}}{\text{day/link}}$ x 10 links = 200 gal day x 30 x 8 mo = 48,000 gal/yr x eff ~ .30 = 160,000 gal

@ $1.00 gal. diesel

C. TEP Basic Contributions

(A) Provides field training of all TEP team personnel. (equivalent to a 6-8 week course)

(B) Provides field training to site personnel. (equivalent to a 4 week course)

(C) Provides technical mission training to managers (equivalent to a 3 week course)

The equivalent cost to achieve the TEP Basic Gains by contract are estimated to be:

(A)	6 people x 40 teams x 5 times around 20k/yr x .1667 yrs.	4000
(B)	10 people x 400 sites x 20k x $\frac{4}{48}$ weeks	6670
(C)	covered in Management	----
		10,670

D. TEP Broad Technical/Engineering Gains

(A) Validated most DCS link engineering.

(B) Provided original reasonable link performance standards and later fully responsible standards.

(C) Justified needed test equipment in tech controls.(System vs box needs)

(D) Validated accuracy of the PMP data.(ICN, RSL)

(E) Found universally poor level engineering throughout the DCS.

(F) Identified many hardware defects.

(G) Identified $(\text{many})^2$ Tech Order errors and voids.

(H) Surfaced many inter and intra site RFI problems.

(I) Found a number of examples of poor site engineering and installation.

(J) Formed basis for first effective Test and Acceptance concept.

(K) Found many cases of slow path degradations.

(L) Found most HF sites have engineering and installation problems.

(M) Found poor support facilities at a number of sites.

(N) Found many sites very poorly engineered (or installed) evidencing high site noise. (correction slow, if at all)

(O) Found poor engineering of many miscellaneous interface hardware and boxes.

(P) Found lack of network engineering.

(Q) Found common failure modes in hardware.

(R) Found poor circuit engineering.

(S) Found most previous T & A was marginal or worse.

(T) Surfaced and justified need for modern test equipment fpr networks.

(U) Surfaced the need for frequency diversity for maintenance.

(V) Validated use of vertical space diversity for ducting links

D. TEP Tech/Eng Gains

To achieve the TEP Gains, the expenditures estimated as indicated below would have been required:

	Study	Dev	Field Test Evaluation	Final Concept and Application Paper	Total
(A)		400 links x	100/link		40,000
(B)	10/link		400/link		4000
(C)	covered under 10 db system gain				
(D)	250		250		500
(E)			1000		1000
(F)	1000		1000		2000
(G)	1000		4000		5000
(H)	10 x 100 links w problems				2000
(I)	covered above				
(J)	250		500		750
(K)			500		500
(L)			1000		1000
(M)	covered above				
(N)	covered above				
(O)			1000		1000
(P)			1000+		1000+
(Q)	500		500		1000
(R)			1000		1000
(S)	covered above				
(T)	est 20% better terminal performance				500
(U)	no claim				
	3000		11,750		61,250

E. TEP O&M $\equiv$ DCS Gains

(A) Created the basis for effective overseas module repair facilities, closely integrated with operational system needs.

(B) Formed the technical and management basis for 'Special Maintenance Teams' that are System, not box oriented. (Proved that the box oriented logistic approach is not acceptable)

(C) Services have applied TEP to non-DCS tails and cables with gains to the DCS. (similar 10 db gains)

(D) Found universally poor HF operation and maintenance.

E. O&M $\equiv$ DCS Gains

The equivalent cost to achieve the TEP Gains by contract are estimated to be:

	Study	Dev	Field Test Evaluation	Concept and Application	Total
(A)	250	250	500	100	1100
(B)	covered elsewhere				
(C)	250		400	200	850
(D)	covered earlier				
	500	250	900	300	1950

F. TEP Spawned other TEP's

(A) Autosevocom Network

(B) Mystic Star Network

(C) Silk Purse Network

(D) Satellite

(E) Autovon Network

(F) Autodin Network

(G) Weatherfax Network

ETC.

These TEP's will lead to the same order of magnitude in management, O&M, technical, and system gains enumerated as outputs for the wideband TEP, and with cost effective gains approximately commensurate with the electronic size of the element since the design, engineering, and installation approach by DOD is generally the same across the DCS. The operational gains will be at least one order of magnitude by almost any performance measure, and larger in most networks.

F. Other TEP's Equivalent est. Costs

	Study	Dev.	Field Test Evaluation	Final Concept and Application	Total
(A)	500		1000	200	1700
(B)	250		2000	250	2500
(C)	100		500	100	700
(D)	150		500	100	750
(E)	500				(very large
(F)	500				(very large
(G)	200		750	100	1050
	2200		4750	750	6700

Appendix II Selected TEP Outputs

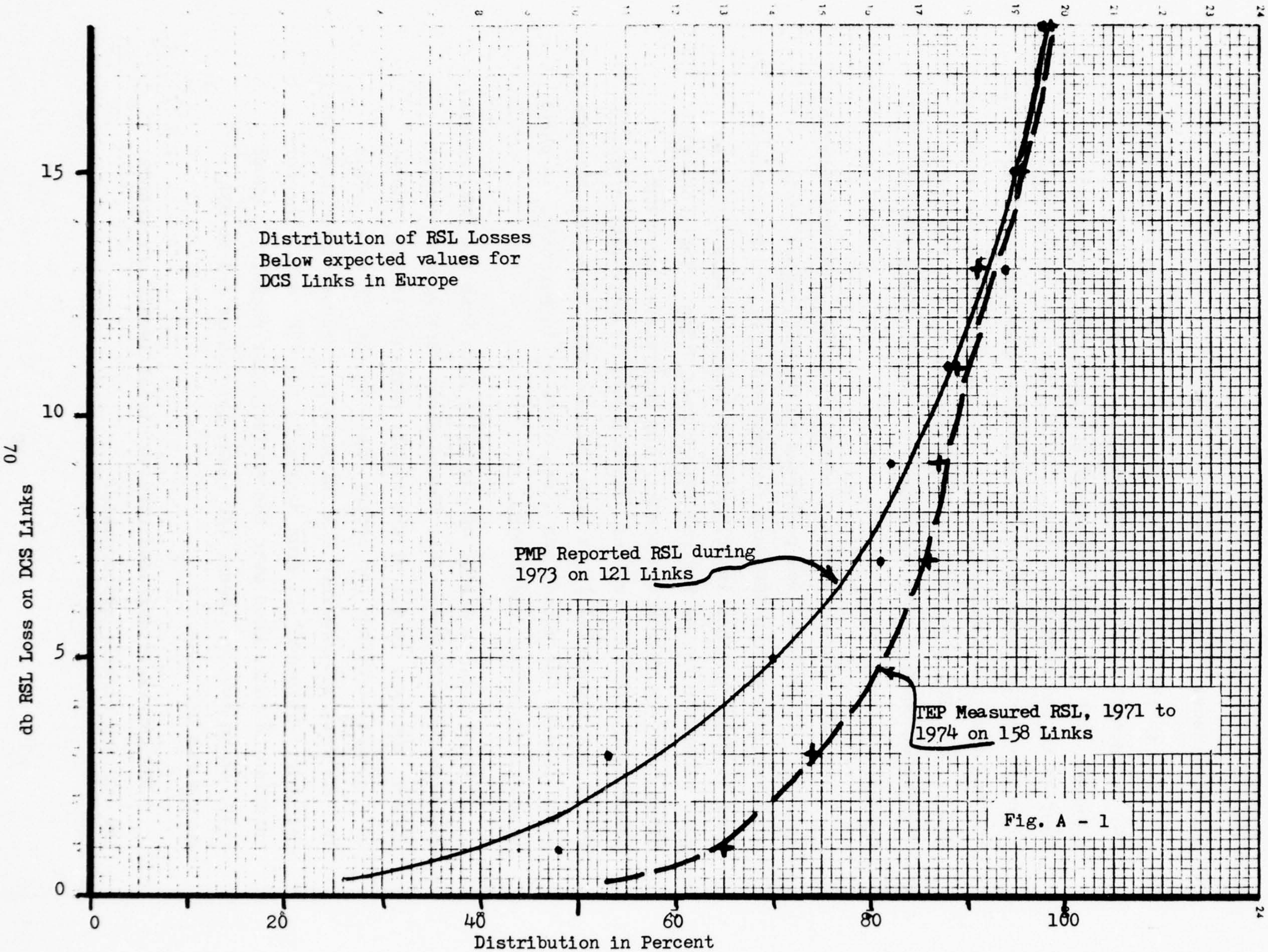
A. DCS Link Receive Signal Level Degradation

One of the very valuable outputs from TEP, was the day-to-day management concept for the wideband structure.(PMP). This program, like all other technical programs, was questioned by many as to its scientific validity, and also its operational effectiveness. These are both legitimate questions. (It's too bad that these same questions are not applied to the whole gamut: the logistic massive paper avalanche, the administrative paper machine, and the management and overhead reports production line).

The PMP reports three key parameters, RSL, ICN, and baseband loading. An analysis was performed on the RSL, since it is also reported by the TEP, and is independent of ICN and baseband loading or other interlocking variations. Thus, it is a good parameter to use for PMP report validation. There are also other built-in validation checks, and each proves good PMP accuracy in most DCA regions. An example, is correlation of the ICN of several serial links with the same path on a long through group used by the author and a few other field personnel to check internal reporting consistency.

Figure A-1, is a plot of the RSL's both from the PMP reports, and also from the TEP. This figure shows very good agreement between the two, in all of the highly degraded links. There is a general tendency for better RSL's in the TEP data. This is both real and proper. The TEP data is recorded after the link has been 'optimized' to some degree by the TEP team. The correlation is thus, good over the entire chart range. It shows that, on an average bases, TEP teams gain about 2-3 db RSL during the TEP work.

The generally degraded receive signal levels throughout the DCS are clearly discernable.


Distribution of RSL Losses
Below expected values for
DCS Links in Europe
PMP Reported RSL during
1973 on 121 Links
TEP Measured RSL, 1971 to
1974 on 158 Links
db RSL Loss on DCS Links
Distribution in Percent
0
5
10
15
20
40
60
80
100
Fig. A - 1

It may be consoling to note that 50% of the DCS links possess RSL's within 2 db of design standards, and have at least 60% of design signal strength. It is of some what less solace to note that more than 40% of the links have lost 50% (3 db) of their expected signal. It is disturbing to note that 14% of the links have lost 90% of their design signal strength (10 db). 5% of the links are 15 db degraded, that is, they are operating with only 3% of the proper RF signal level. Recall that these dismal numbers are validated by both TEP and PMP in complete agreement. Those who believe that the digital world will solve all FDM problems, may or may not be correct, but poor receive signal level is not an FDM problem, it is a universal propagation problem faced by any radiating scheme VLF through the UV spectrum. In the case of the DCS, it is not clear whether the problem is bounded and controlled yet or not.

B. Baseband Loading Variation

Another output from the TEP offspring PMP program is the curve of Change in Baseband Loading, Night to Day , for DCS Links. This data is interesting just as a fact relevant to the operation of the DCS. There is a better reason, however, for attention to this curve, Figure A-2. (This data should be refined by plotting more data than was available to the author).

In another report prepared under this contract, a relationship was derived between ICN, baseband loading and NPR. This curve appears in the TEP Analysis Program as Figure 2-7. This 3 parameter inter-relationship varies to some degree depending upon the type equipment, but several broad truths emerge.

1. Assuming that the link is <u>properly</u> designed, operated, and maintained, and further, recognizing that the actual baseband loading is usually observed to be 6 to 9 db less than CCIR;

   a. the expected baseband loading variation night to day of 2.8 db, will produce less than 1 db change in ICN.

   b. the ICN variation from the normally light loading to full CCIR, will be no more than 3 db.

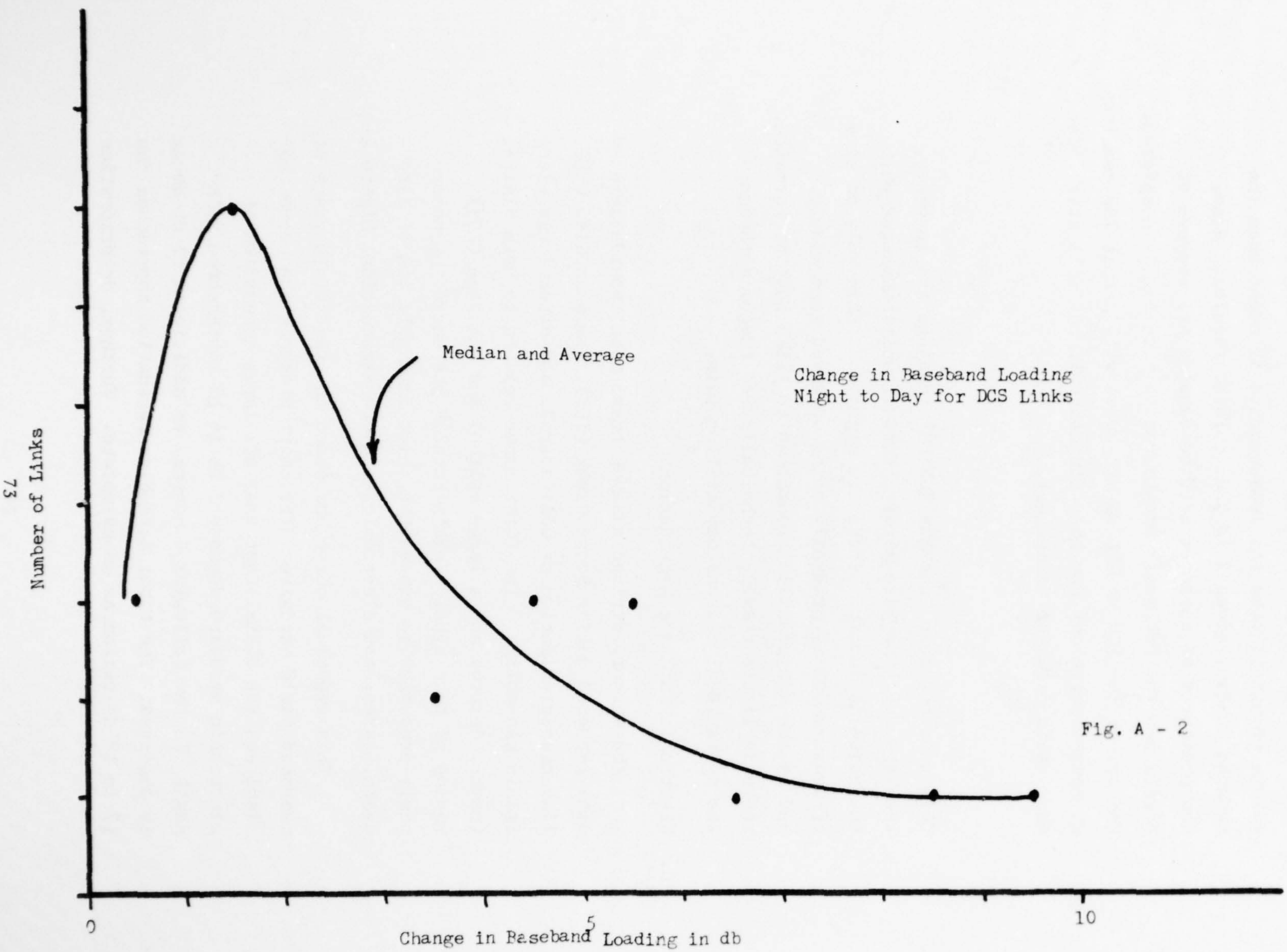
2. Assuming that the link is maintained and operated in '<u>average degraded</u>' condition;

   a. the baseband loading variation night to day of 2.8 db, will produce ICN changes of 3 to 4 db.

   b. the result of imposing full CCIR loading will produce ICN degradations as high as 10 db.

Consequently, day-night variations in excess of 3 db, are by themselves, an indication of degraded operation or maintenance on a link. (with very few exceptions).

A corollary to the above, is useful in examining the PMP reported ICN data. Unless the admonition to the field to conduct the PMP measurements at varying times around the



Number of Links
Median and Average
Change in Baseband Loading
Night to Day for DCS Links
0
5
10
Change in Baseband Loading in db

Fig. A - 2

clock is rigorously followed, the field personnel are astute enough to make the measurements at night when the reduced loading gives 2 to 5 db quieter results. Also, the pressures of customer service demands are reduced at night, and the PMP measurements can be more easily completed. The use of the ICN vs BBL vs NPR curve will permit PMP readings at convenient times for the tech control, but will still produce valid data for management.

This does not mean that the ICN PMP readings are in error, they are not, they are merely 'fortuitously' measured when the noise is lowest. There are signs that this rule on time of measurement is gradually being observed more widely, and as the equipment is brought up to 'like new' performance, there is little reason, technically, to fudge, although, the operational reasons may still remain.

C. Electronic Hardware Degradation

The author, derived a curve based upon considerable data gathered during Scope Creek (TEP), Commando Glow (TEP like characterization of GCA radars), and other large electronic assemblies. The first curve related to both digital (radar, crypto, and a large switch) and analogue (FDM) radios of tube type. Feik's Fatal Facts curve is humorously presented to expose the third immutable law of life - death, taxes, and electronic hardware degradation. Figure A-3.

This emperical curve has stood the test of 10 years of measured field hardware. The chart presents the curve that discloses the dismal fact that all large assemblies of electronic hardware degrade 3 db in 12 months from 'like new'! In the following 6 months, an additional 13 db decay is observed. The total assembly degradation approaches the 17 to 18 db region as an asymptote. Further, deterioration

in performance does not occur gracefully, but rather abrupt failure terminates the operation entirely. Repair of the failed element restores the assembly to its 17 db degraded performance level, ie., operating at only 2% of 'like new.' A FDM/FM structure is judged by the channel performance and ICN follows a similar although not identical curve. These truths, in part, helped sell management in the DCS, on implementing the PMP.

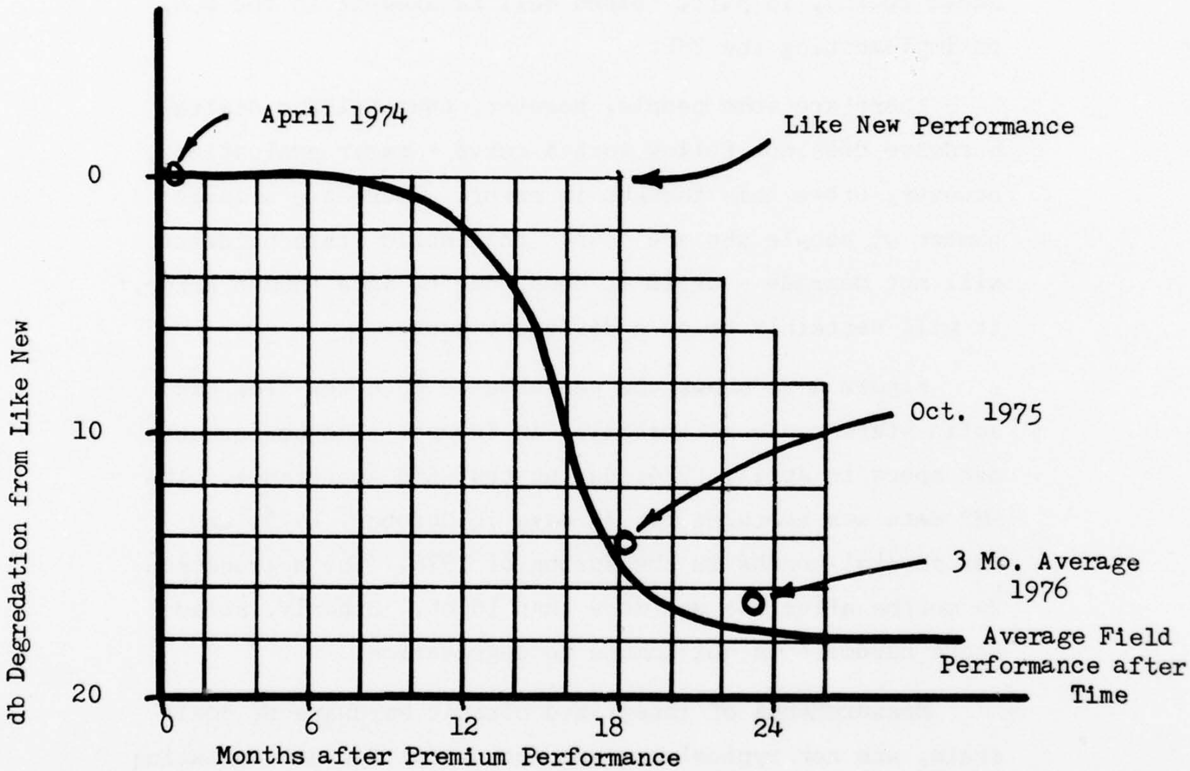
There are some people, however, that believe digital hardware does not follow such a curve - radar evaluations, however, prove this thought in error. There are a large number of people who are 'sure' that solid state hardware will not degrade - or if it does, due to some 'human error,' it will certainly be on a different curve.

Figure A-3, shows the performance on a new "low bid" solid state radio as installed in Europe. The performance met specs in April, 1974, during test and acceptance. The PMP data was averaged for 30 days in October, 1975, and for several months in the spring of 1976. The degradation 24 months after T&A was more than 16 db. Clearly, solid state hardware is not immune to degradation.

Measurements of integrated circuit hardware of small scale, are not typical and are not useful for extrapolating to derive performance of large scale entities. Integrated chips often have very long stable and reliable operation, but that is of partial interest in large assemblies. Cables, connectors, induced failures often by humans, but possibly by a failure elsewhere in the circuitry, poor environmental control, spurious signal pick-up, lightening hits nearby, etc., are still present, and are not materially different in the solid state integrated circuit world, so tend to be the forcing decay factors.

It is true that well designed properly manufactured and correctly installed solid state equipment has a degradation

FEIKS FATAL FACTS



Typical Operating Conditions of Communication System Major Elements.

Fig. A - 3

curve somewhat longer term than shown - in that the time period is extended several years, but the asymptote is about the same. This point is very important!

In spite of the absolute certainty that digital hardware, including PCM/TDM hardware, and computer complexes, will degrade generally as indicated, there is no similarity in the performance of the structure as viewed by the user. Rather, the user sees nearly stable operation until just before the erratic performance short lived precursor to complete failure.

The point from this TEP derived data is clear. If premium performance of FDM or TDM is to be assured, the inexorable degradation progress along this general shape curve must be assessed, fault isolated, and corrected prior to failure and loss of customer service.

D. Equalizer Modules

There are many ideas that surface during any in-depth examination of TEP reports. Some of these ideas are especially useful when they relate to a chronic problem, or relieve a widespread difficulty in the DCS. The idea for a plug-in equalizer module with no adjustments is one such idea that developed during this contract TEP report analysis.

Measurements on the degradation induced to signals as they traverse the DCS has disclosed that the conventional equalizers installed in the field are actually causing added deteriorations beyond that of the circuit itself. In many cases, the operation was considerably less degraded when the equalizer was removed from the circuit, and in most cases the conditioner was of little impact in either improving or degrading the signal. Yet, the basic circuits were not linear and would benefit from a properly - but only a properly - aligned equalizer.

Some previous work, done by the author and Dr. Y.S. Fu, now of DCA, and published in 1972, formed a basis for a reexamination of this problem.

Figure A-4, shows the composite envelope delay for a large number of 8 types of DCS multiplexs in widespread use. The $\pm$ 1 sigma spread of the data (approx. 68%) is not large and is generally the same for all mux types, except the UCC-4. The UCC-4, Figure A-5, is a bit better at the lower frequencies, and considerable improved above 2200 Hz, and the $\pm$ 1 sigma spread of the delay is much reduced. In all cases, the curves represent a mux voice channel pair - two breakouts to audio would double the envelope delay portrayed.

It is obvious that if envelope delay is known, then it is possible to construct a fixed module to compensate appropriately. It is clear that a module could be built to equalize an average channel. Figure A-6, shows three curves:

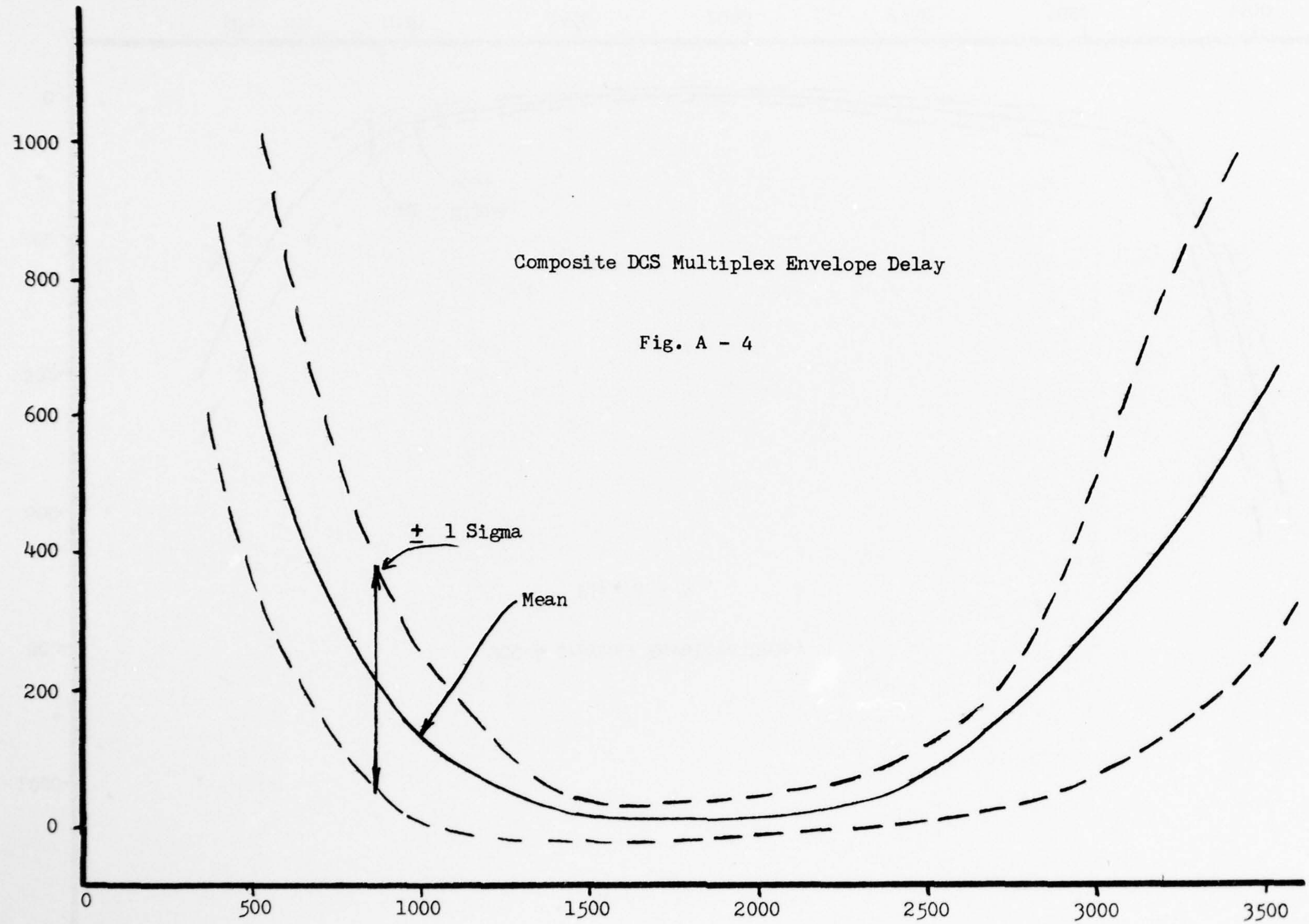
a. a 'perfect' equalizer for the UCC-4.
b. a 'perfect' equalizer for the DCS 'composite' mux.
c. a compromise equalizer for use with any mux in the DCS.

Figure A-7, shows the results of using a hypothesized DCS Standard - (compromise) - envelope delay equalizer with an average DCS mux. The S-3 specs are easily met and the delay curve is smooth and well controlled to below 300 Hx and above 3300. This is a great improvement over present adjustable equalizers.

Figure A-8, shows the results of this same non-adjustable equalizer applied to the UCC-4. The channel is a bit over compensated, but still well behaved over the entire band of interest.

The merit to this idea is large from several aspects:

a. There would be no adjustment on this equalizer, so no talented maintenance personnel or test equipment would be required for initial setup. Further, there

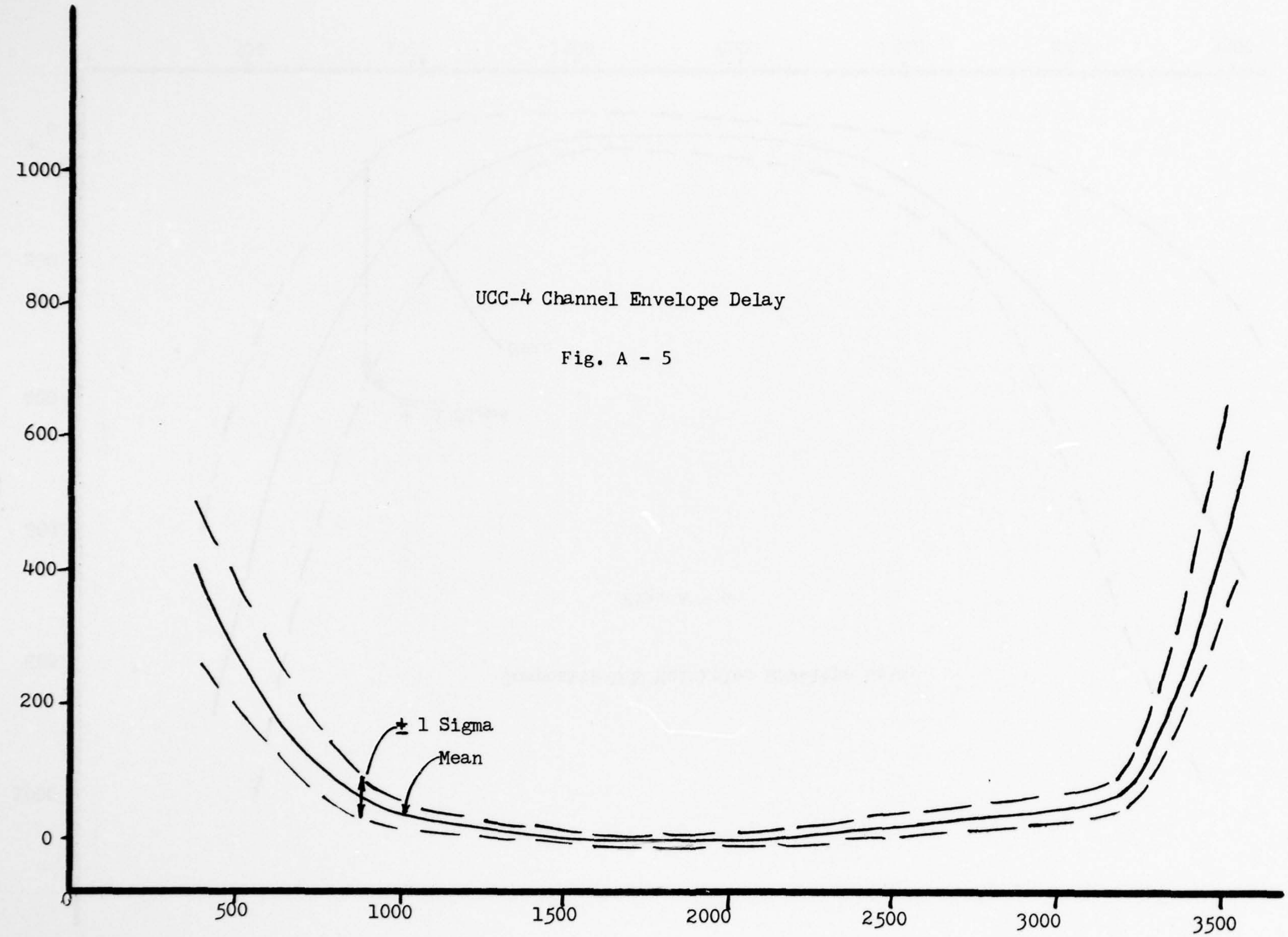


Composite DCS Multiplex Envelope Delay

Fig. A - 4

UCC-4 Channel Envelope Delay

Fig. A - 5



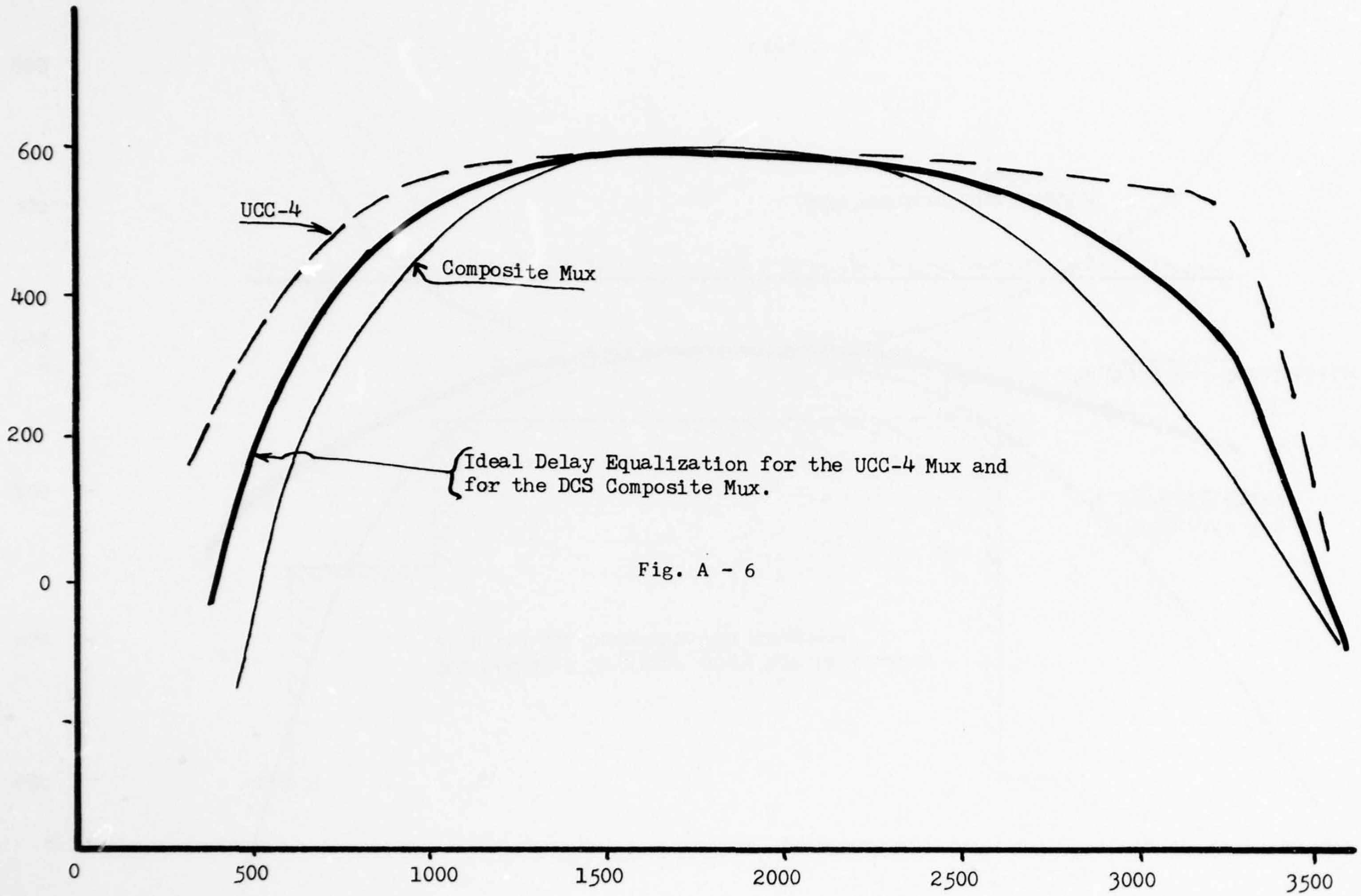
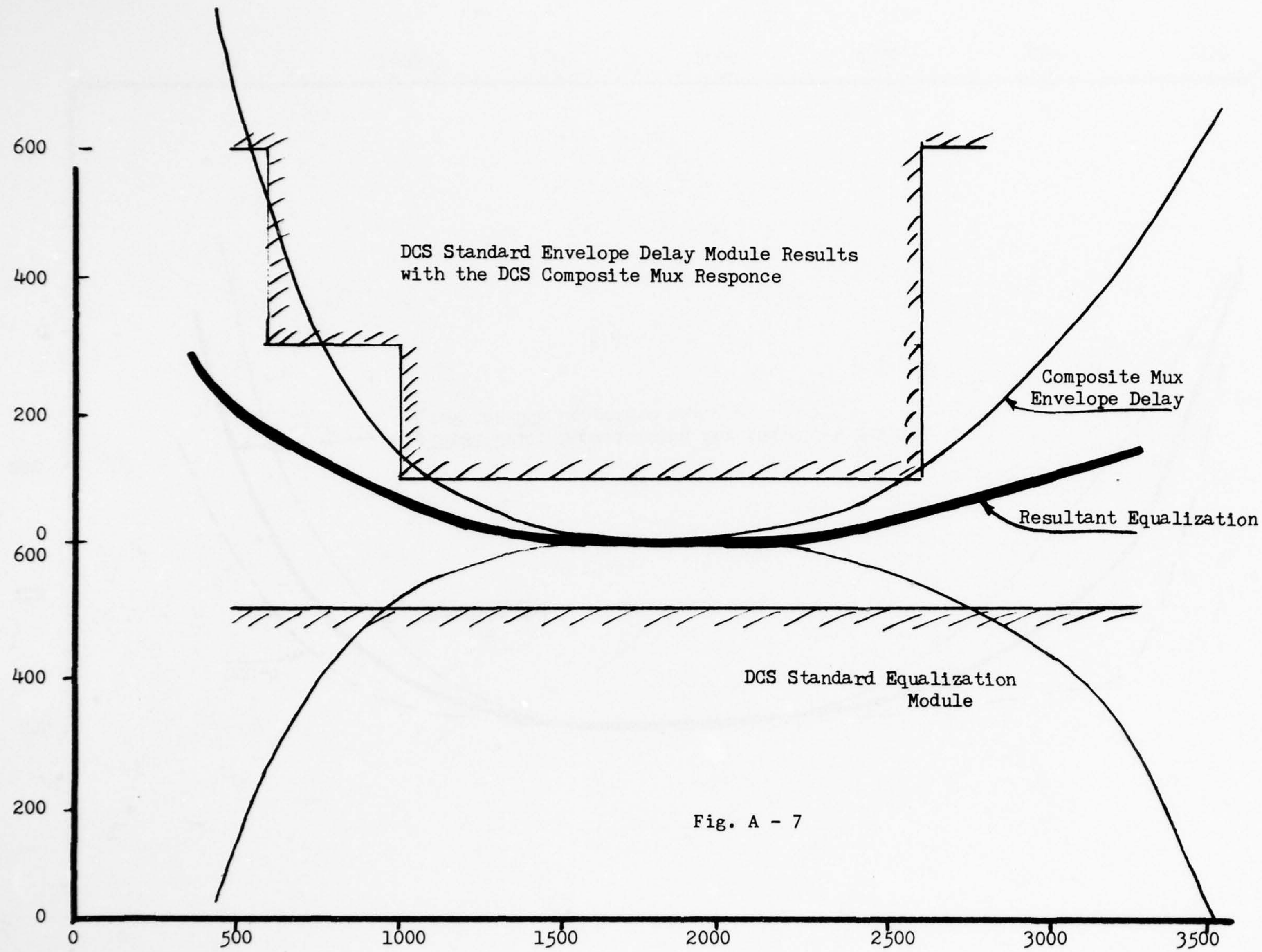

600
400
200
0
0
500
1000
1500
2000
2500
3000
3500
UCC-4
Composite Mux
Ideal Delay Equalization for the UCC-4 Mux and
for the DCS Composite Mux.

Fig. A - 6



DCS Standard Envelope Delay Module Results
with the DCS Composite Mux Responce
Composite Mux
Envelope Delay
Resultant Equalization
DCS Standard Equalization
Module
600
400
200
0
600
400
200
0
0
500
1000
1500
2000
2500
3000
3500

Fig. A - 7

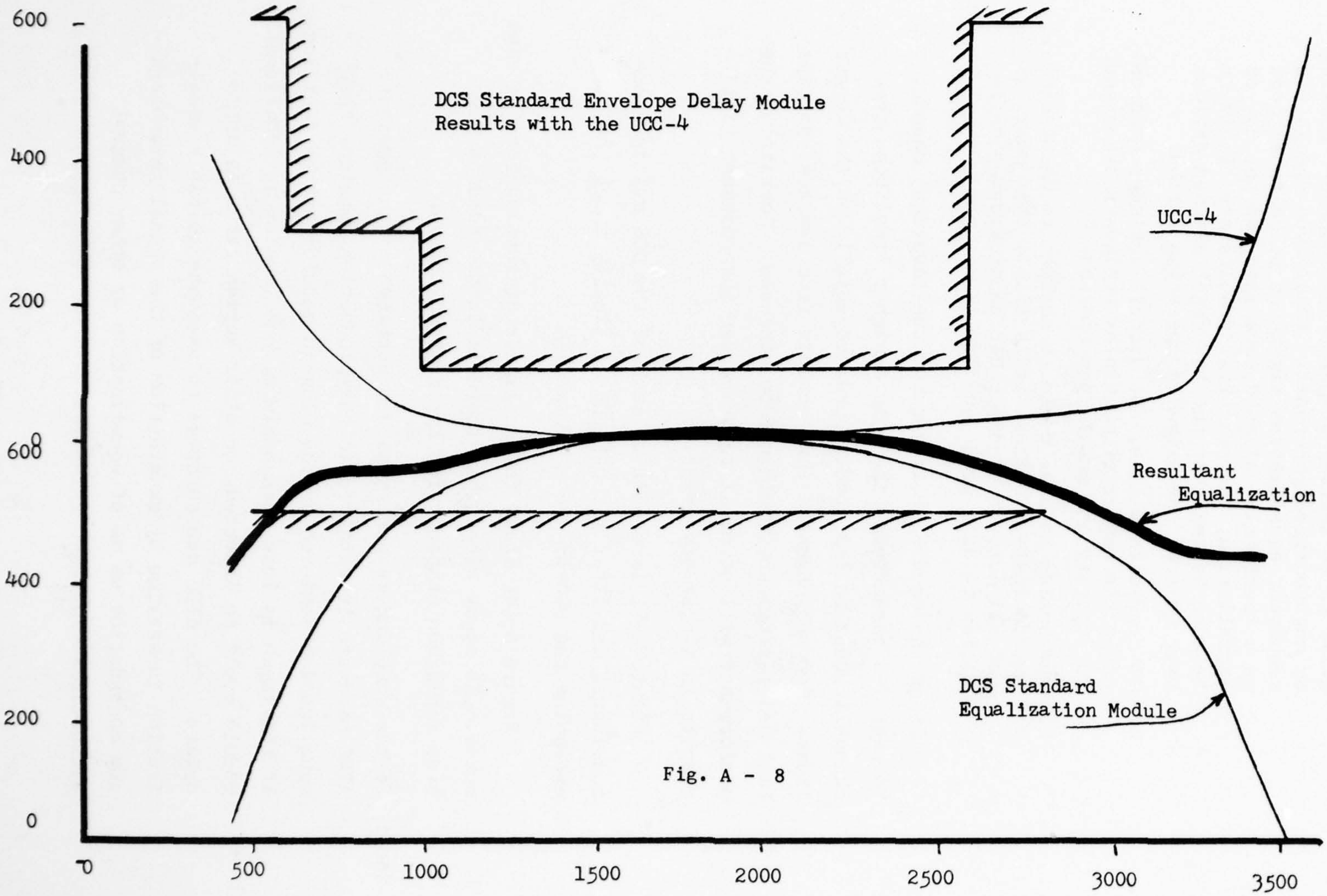

DCS Standard Envelope Delay Module
Results with the UCC-4
UCC-4
Resultant
Equalization
DCS Standard
Equalization Module
600
400
200
600
400
200
0
0
500
1000
1500
2000
2500
3000
3500

Fig. A - 8

would be no way to disturb the adjustments accidentally, or to destroy alignment by improper 'peaking' by unauthorized personnel. Thus, even though the resultant equalization might not be quite as good as a 'perfectly' aligned equalizer, on the day of installation, the practical results are likely to be much better than the 'average' aligned device over most of the extended operating period.

b. To condition a line, the circuit engineer need only count the number of multiplex breakouts traversed, and specify one module per breakout.

c. The sealed modules would be cheaper to manufacture, and to install. Thus, it is likely that most, if not all Autovon trunks could be provided equalization to data grade quality.

Since the equalizer is set for the 'average' channel to meet S-3 parameters, there is a higher likelihood that channels would be S-3 conditioned, especially on the longer links. For the channels that deviate from average, perhaps full S-3 performance would not be achieved. Certainly, the performance will be equal to or better than present field results in almost any event.

Figure A-9, is a plot of each of the DCS multiplexers considered and clearly shows the similarity among the types - excepting the UCC-4.

Figure A-10, shows the amplitude distortion for the same muxes. It seems clear that there is little need to fret over amplitude compensation for most DCS usage.

Note: If the sampling mechanism as demonstrated by the present ATEC hardware is retained in the production version, the equalization achieved by the plug-in modules can be verified. If the match is less than optimum, one less or an additional module could be inserted, or other action taken as appropriate. The ATEC can continue to validate suitable equalization in-service by examination of the signal parameters - any degradation warns of equalization or other channel distortion.

VF CHANNEL DELAY DISTORTION

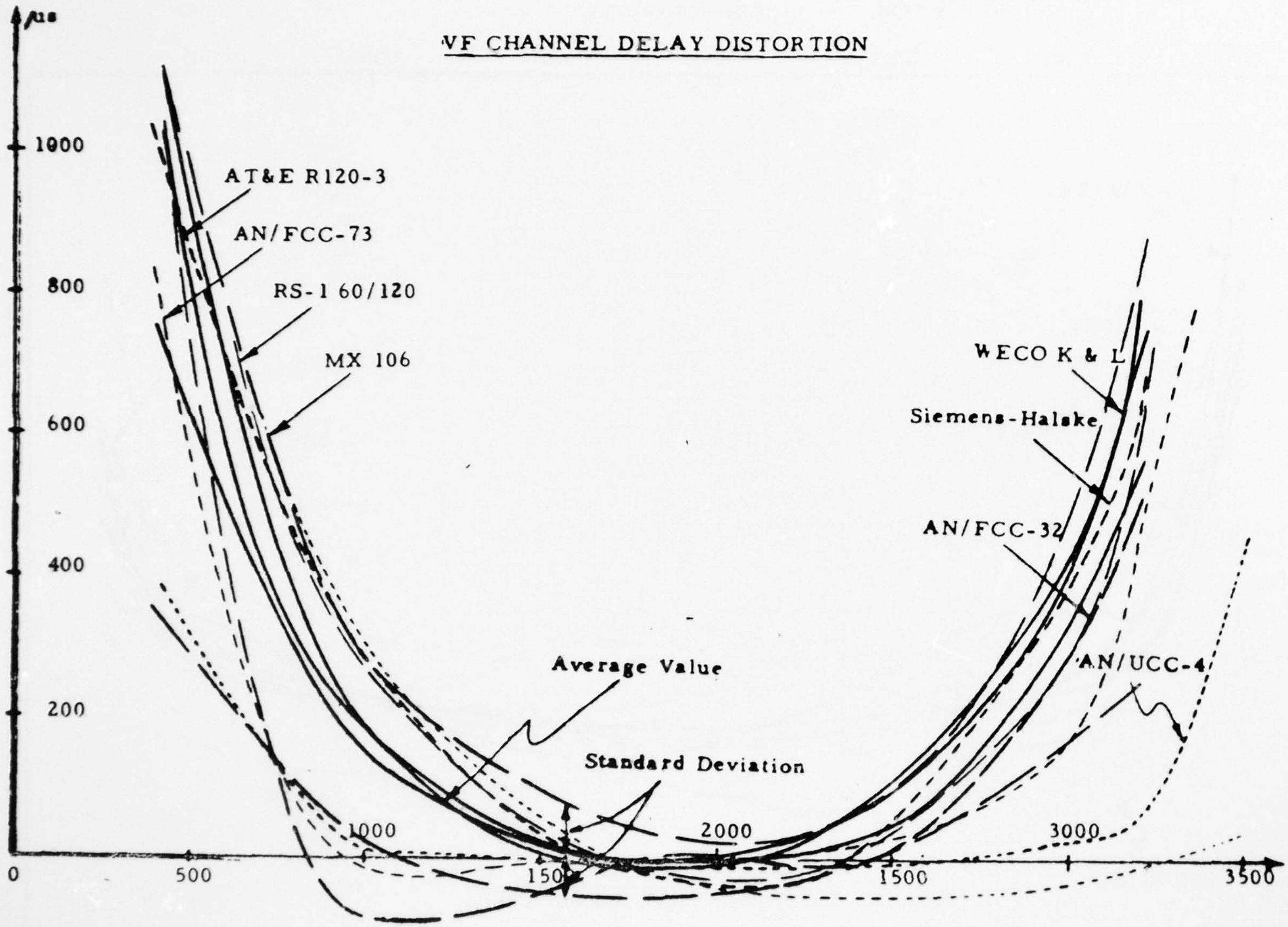


Fig. A - 9

OA 152

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TEPER TECHNICAL EVALUATION PROGRAM EVALUATION AND RESTRUCTURING--ETC(U)
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UNCLASSIFIED RR-2-77 RADC-TR-78-121 NL

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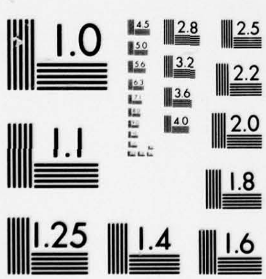

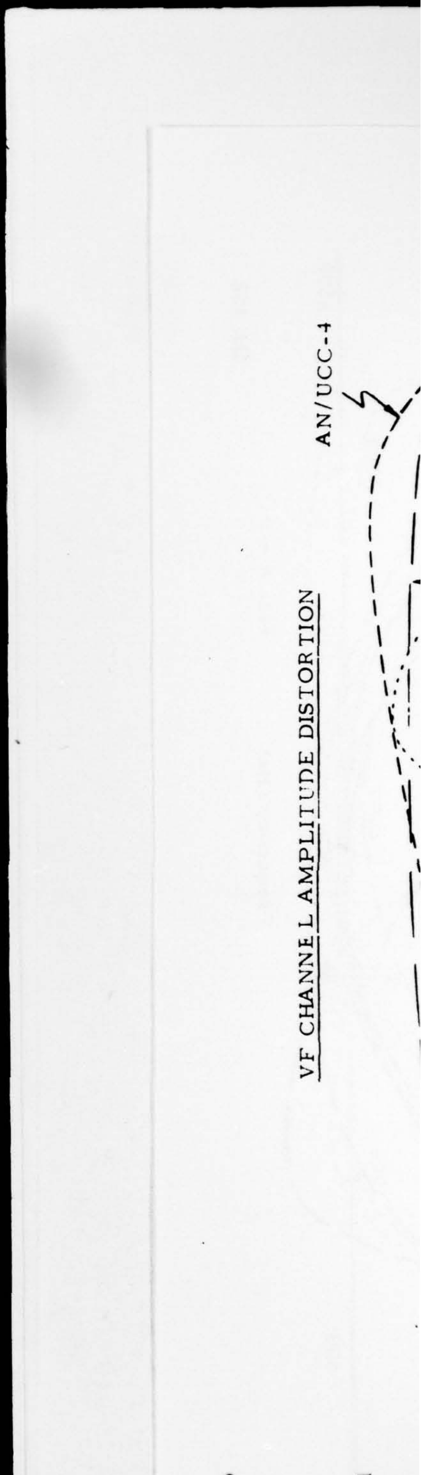
VF CHANNEL AMPLITUDE DISTORTION
AN/UCC-4
db
+1

VF CHANNEL AMPLITUDE DISTORTION

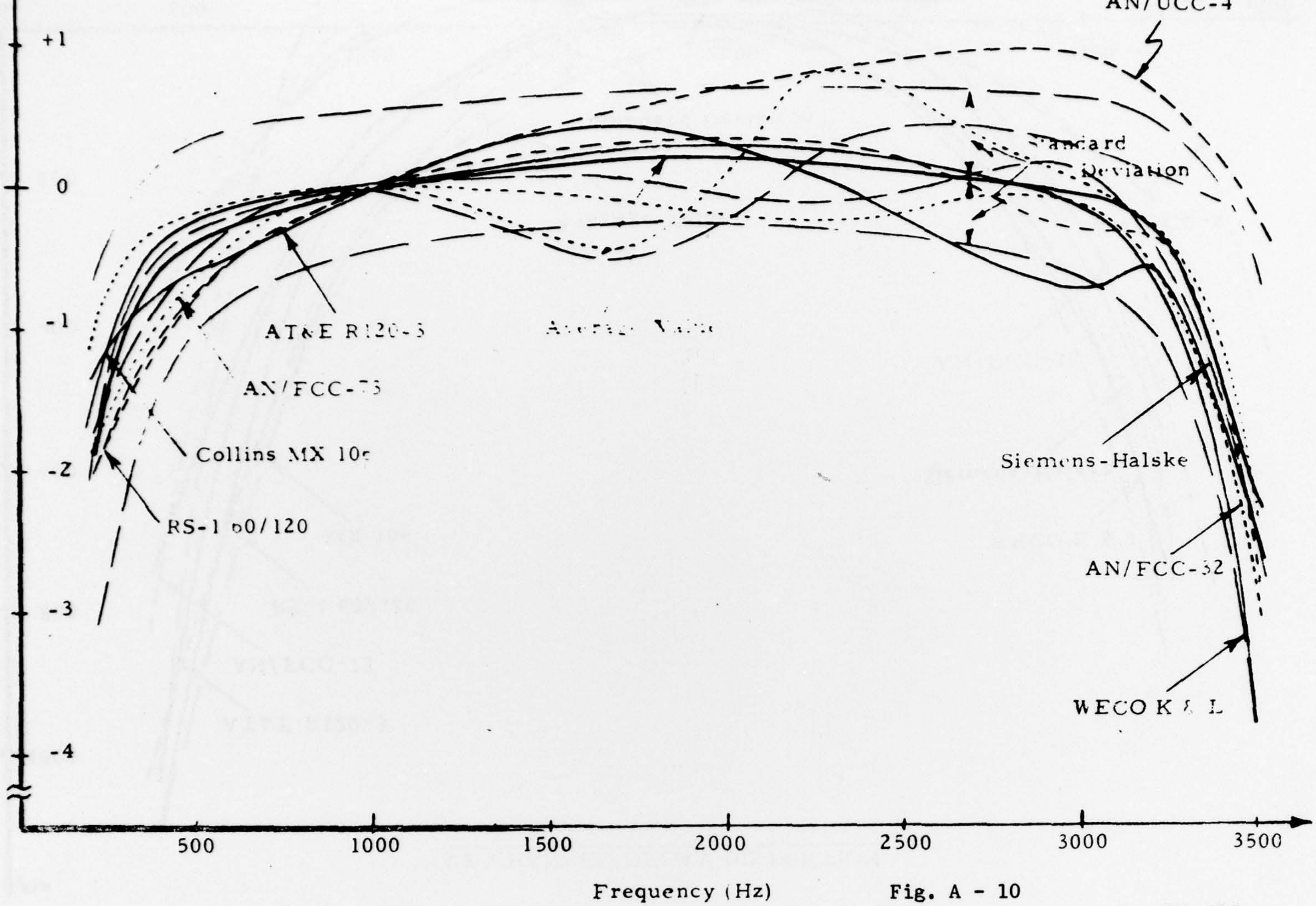

Fig. A - 10

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